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DEVOTED TO

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FOR THE

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EDITORIAL.

Notice.—The publication of the Journal is made under the direction of the Editor and the Committee of Publication, who endeavor to exercise such supervision of its articles, as will prevent the inculcation of errors or the advocacy of special interests, and will produce an instructive and entertaining periodical; but it must be recognized that the Franklin Institute is not responsible, as a body, for the statements and opinions advanced in its pages.

Technical Education of the Engineer.—At the recent meeting of the Institute of Mining Engineers in this city, a discussion upon the subject of technical education was resumed from the Washington meeting of March last, and by invitation was participated in by members of the Society of Civil Engineers, thus obtaining opinions on this subject from the practical men of both of these branches of the profession. This discussion did not embrace all technical education, of which law or medicine, or surgery, with chemistry as an offshoot from the latter, are the older technical studies; but was limited solely to the recent additions to knowledge; which the modern developments of mechanical or industrial pursuits have produced. Neither was that most essential of all technical avocations, the writer or teacher, fully represented in the

expression of views, and the results of the consideration which they have been especially called to give to this subject, were not so fully expressed as could have been wished. The information elicited, therefore, was narrowed down to what, in the opinions of the practical engineers, should be the proper acquirements of a young man in learning, precedent to the commencement of a career, upon which to predicate a ready and successful exercise of mining and civil *engineering ability.* The recognition that mathematical attainments of a high order were as desirable, if not needful, to the engineer as the ability to use a language and write it out is to a poet, was, if not asserted in these words, a fair statement of the conclusions of most of the speakers. The corresponding averment that mathematical or other intellectual attainments would *not* qualify a man to be an engineer, any more than the most thorough knowledge of the dictionary and grammar would confer the poet's faculty, was *not* so definitely averred.

The sense of deficiency in both general and particular knowledge was the uniform admission of all the speakers, who were, for the most part, the older and most experienced practicing engineers of the day. Forty years ago the profession was scarcely to be be considered what was then called a "liberal one." The collegiate course of that time, which gave a smattering of chemistry and physics, with, however, a very fair course of higher mathematics (with a somewhat inadequate presentation of applied mechanics especially referred to forces of moving bodies), was not thought to be part of the requisite education of the foreman mechanic, which was about the standing of the engineer of the time. Most of the older engineers of to-day (who were the scholars of forty years ago) are men who from mere force of personal ability have attained their present position, and who by intuitive knowledge—by experience and personal observation rather than by study, and by incessant and arduous labor, have built up their reputations. Those who have reached eminence have inevitably come to appreciate the learning of the schools, and have availed themselves of any aid and all means in following out their undertakings; the mathematician, the physicist, the chemist, the geologist or the linguist, all have been employed as occasion demanded, in the same way that labor has been used or material purchased. Still the *want of information* has been seriously felt when prompt action or independence of thought were requisite. Errors in plan and in construction, in comprehension

originally, or accomplishment in the end, always difficult to obviate, and sometimes even when trivial, insurmountable, have embittered the life of the most successful director of work. Each engineer knows in his heart how close upon failure, constructedly or financially, his most successful and esteemed undertaking or accomplishment has at one time hung in the balance, and how the defect which formed the obstacle to be overcome or palliated was one which *knowledge* would have avoided. Where the knowledge, which was at such a moment so essential, was to be found—in whose teaching, or whose practice, in what book, or from whence to have been derived—from what course of study, even in what language, could not be designated, and it was, consequently, generally concurred in by all speakers, that the broadest and most general education was not too extensive in its scope for the foundation of a young engineer's career!

This happy conclusion leaves the main point as inconclusive as ever.

The technical education for an engineer that is really to be considered, is necessarily a limited one. It is how to impart in a four years' course to a young man who has had a common school education, which has developed little more than mnemonic ability, and the semblance of deportment, but whose friends have decided to educate for an engineer, the *essential* mathematical, physical, and other knowledge which every day's practice of the profession will call into use, and as much more for "breadth" as the capability of the pupil will admit. It is to be regretted that the common school education does not develop or foster latent powers, so that the youth of sixteen to seventeen years of age, who has completed his "course," and is a candidate for the freshman class of the "Technical School," although he may actually be in possession of that mathematical or mechanical *ability* which alone will ensure a successful career in the engineering profession, yet unless highly marked in the boy (when it is generally erratic in the man), will have given few outward indications in advance of the completion of studies, on which even a guess as to suitableness of avocation can be based.

It is a serious subject for comment as to whether the progress of the common school system in its rigid uniformity, is not retarding the especial growth of individual ability, and forming a limit to our higher advances in knowledge. Both mathematics and the languages, require that more than a foundation should have been attained by the youth of sixteen or seventeen, if he is to be eminent in them in future

years. Especially the mathematical capacity, which is so essential to the engineer, can be fostered and developed in the boy, but it cannot be taught. Not one-half of all the pupils of the schools in the land can comprehend the processes of simple arithmetic. The attempt was made with Colburn's arithmetics, thirty or forty years since, to teach the relations of figures by pure reasoning alone, with admirable success for one-third the scholars, by great drilling with another third, and with complete failure for the remainder; until after many years' trial, the system of rules, with explanations to those who could understand, was again returned to. For the purpose of every day life the rule, even with only a semi-consciousness of reason for it, at one time in one's boyhood, will answer; but for aptitude in the use of figures, such a knowledge as never calls for the recollection of words, however expressed, is indispensable, and for progress in studies, the learning of a rule is a detriment to the reasoning faculty.

The youth who are entered to our technical schools with a view of becoming engineers, are unquestionably selected with some regard to their capacity to receive the peculiar instruction, while examination puts out many that are incapable or deficient; still the fact remains that the standard for admission is undeniably low. It would be very well if in the upper schools of our common school system, and as for that matter, if from the primary schools upwards, more attention could be given to the education of individual pupils, so that the point of departure of technical school education of all kinds could be elevated from the present one. Could this be effected, the entire character of our national collegiate education would be placed in better accordance with that of other civilized lands than at present. . . .

There is another aspect of this subject of engineering education, singularly not referred to by any of the speakers; to which attention should be called, that is, the special requirements of a technical learning for engineers, which shall impart to the student the particular professional information which he should be taught. This proposition of teaching on engineering subjects involves three conditions: first, that there shall have been an observer, whose knowledge, both of methods and accomplishments, has taken the form of a *record;* second, that there shall have been an investigator, whose reasoning shall have enunciated a *science;* and third, that there shall have been an instructor, whose *theory* has comprehended the adapta-

tion of the recorded construction, and the application of the investigated science to other purposes or ends. The availability of the learning, in practical use to the student when he emerges as a graduate from the schools, depends upon the fulness and accuracy of the record—the thoroughness of the investigation—the soundness of the theoretic teaching. It is to be feared that the schools themselves have more knowledge to acquire from the practice of the engineer than they can impart to the pupil, who is expected to succeed and follow in that practice. The text books of all languages, and of the English language especially, are far from complete or accurate in their record, description or illustration of actual practice or results, in engineering or mechanism. Each new text book reproduces largely what the author considers available from older authorities, and errors or mistakes are perpetuated with the same fidelity that the correct, but possibly antiquated, schemes have been delineated or described; while the additions of new matter are rarely made with knowledge of the distinction between practice and project. The deficiency of text books is more marked in constructive details, the mastery of which is the test of all engineering, than in arrangement or disposition of parts, or in the whole of erections or machines. This want is so complete, that a thorough knowledge of book learning only graduates a pupil as helpless as if he were without hands. But the "science" of the text books, as applicable to the requirements of work, is by no means as reliable or trustworthy as could be desired. Much skill, ingenuity and ability have been evinced by the best writers, in the statement of physical laws in oracular words, happily expressed after the style of legal opinions, so that unnoticed qualifications shall be traps to those who endeavor to use them; but real error has not unfrequently accompanied the most dogmatic conclusions. At times, science has been a stumbling block and not an aid to the engineer.

Take for a ready instance, the demonstration, that the expansive effect of steam in a single cylinder engine was identical with that in the double or compound engine, which destroyed the prospects and broke the heart of Hornblower nearly 100 years ago. For 70 or 80 years the law of the force of expansion in a steam cylinder was taught in all the books as following the curve of hyperbolic logarithms, until about 1850 it was discovered that this curve did not at

all express the practical occurrence—some of the conditions of steam, heat and work had been unconsidered. It has been recognized at last that to impel a crank engine by means of a single cylinder with a high expansion, was or is, as practicable as to drive it by the fall of a pile driver ram. The mechanical effect of a sledge hammer is as surely expended on the anvil as it is represented by the lifting of the hammer before it fell ; but he who should essay to turn a grindstone by hammering the crank would unfailingly come to grief, or at least the crank would, which is what happens to the single cylinder engine. The strength of beams may be taken as a ready instance of the incompleteness of theoretical investigation. We *know* the tensile strength of materials within limits of imperfections of the materials themselves, and the crushing strength within limits of those same imperfections as locally distributed in the length under compression ; but the cross strength of even a perfectly homogeneous material can only be estimated by some hypotheses of neutral axis, which, neglecting the internal strains in a web, call for an assumption of a new tensile or compressive strength. To be sure the most thorough writers have indicated the correct method, in discussing this subject (Lamé on the Elasticity of solid bodies), but the text books teach with unqualified dogmatism.

The past hundred years have witnessed the growth of modern civil and mechanical engineering. The crude efforts of those who took the early steps can no longer be accepted as capable of giving distinction or position to our younger engineers. Telford is not an authority on bridge construction. Smeaton would be lost in designing a lighthouse. Watt would be incapable to construct a first-class modern engine. Stephenson would not now be trusted to construct a railway. Morse could not direct the running of a new line of telegraph. Daguerre would be lost in a photograph gallery. The initiatory labors of these great men are now a part of the history of engineering; their record forms a paragraph in the book which the young engineer must study. As surely as development and growth are processes of improvement and accretion, so surely does the progress of engineering in all its branches have its basis upon the preservation of present attainments by record, and making them available for future use by teaching to the student who shall become the engineer hereafter.

Franklin Institute.

Hall of the Institute, June 21, 1876.

The stated monthly meeting was called to order at 8 o'clock, P.M., Vice-President, Chas. S. Close, in the chair.

There were present 76 members and 9 visitors.

The minutes of the last monthly meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting the following donations were made to the library:

Thirteen Numbers of the Journal of the Franklin Institute for 1874–75. From Chas. Bullock.

Seventh Annual Report of the American Railway Master Mechanics' Association in Convention at Chicago, May 12th, 13th and 14th, 1874. Cincinnati, 1874.

Report of Proceedings of the Eighth Annual Convention of the American Railway Master Mechanics' Association held in the City of New York, May 11th, 12th and 13th, 1875. Cincinnati, 1875. From J. H. Setchel, Secretary.

Journal of the Royal Geographical Society. Volume 45th, 1875. From the Society, London.

Art Directory, containing regulations for promoting instruction in Art, with appendix.

Directory with regulations for establishing and conducting science schools and classes, &c.

A Guide to the South Kensington Museum, London. From C. B. Worsnop, S.K.M.

Archives du Music. Teyler. Vol. 4. Fasicule, premier, 1876. From the Directors.

Reports of the Secretary of the Treasury on the Construction and Distribution of Weights and Measures. Washington, 1857. Ex. Doc., No. 27, 34th Cong., 3rd Series. From J. E. Hilgard, U. S. Coast Survey.

Records of the Geological Survey of India. Vol. 8, Parts 1–4, 1875.

Memoirs of the Geological Survey of India, &c., &c. Jurassic Fauna of Kutch. Vol. 1, 2, 3, Series 9, 1875. From the Geological Survey Office of Calcutta, India.

Specifications and Drawings of Patents for Dec., 1875. From U. S. Patent Office, Washington.

New Encyclopædia of Chemistry, to be completed in 40 parts. Published by J. B. Lippincott & Co., Philadelphia. From the Publishers.

Notes on the Treatment of Mercury in North California. By T. Egleston, Ph.D. Philadelphia, 1876. From the Author.

Amphiorama ou la vue du Monde, par F. W. G. Trafford.

Further Notes on "Inclusions in Gems, &c.," by Isaac Lee, LL.D. Philadelphia, 1876. From the Author.

Verhandlungen des Naturhistorisch Medicinischen Vereins zu Heidelberg, neue folge, erster band, drittes heft, 1876. From the Society.

Solar Investigations, by John Erricson, LL.D. New York, 1876. From the Author.

Hand-book of Modern Steam Fire-engines, including the running, care and management of steam fire-engines and fire-pumps; by S. Roper. From Claxton, Remsen & Haffelfinger, Publishers, Philadelphia, 1876.

Food Chart; giving the names, classification, composition, alimentary value, rates of digestibility, adulterations, tests, &c., of the alimentary substances in general use. By R. Locke Johnson, London.

Statistics, Medical and Anthropological, of the Provost Marshal-General's Bureau; derived from records of the examinations for military service in the armies of the U. S. during the late war of the rebellion, of over a million recruits, drafted men, &c., &c. Compiled under direction of the Secretary of War by J. H. Baxter. In two vols. Washington, 1875. From J. H. Baxter, A.M., M.D.

A Brief Treatise on United States Patents, for Inventors and Patentees; by Henry and Chas. Howson, Philadelphia, 1876. From H. & C. Howson.

Statistics of Mines and Mining in the States and Territories west of the Rocky Mountains; being the sixth annual report of Rossiter W. Raymond. Washington, 1874. From Chas. O'Neil, House of Representatives.

Papers read before the Pi Eta Scientific Society, 1876; Rensselaer Polytechnic Institute, Troy, New York, 1876. From the Society.

Centennial Newspaper Exhibition, 1876. Complete list of American newspapers, &c., compiled by G. P. Rowell & Co., N. Y., 1876. From the Compilers.

The order of business was changed so as to now take up deferred business, under which head the subject of the adoption of the Majority Report on the Metric System of Weights and Measures was taken up.

The questions being on Mr. Chabot's motion to still further divide Mr. Jones' motion, so as to make the question of the adoption of the

report one resolution, and sending a copy to the Boston Society of Civil Engineers another; it was adopted.

The question then recurred, on Mr. Jones' motion to adopt the Majority Report of the Committee on the Metric System of Weights and Measures, and it was being discussed when, on motion of Prof. Houston, the further consideration of the subject was postponed to the stated meeting in September.

The Secretary presented his Report, embracing an illustrated description of the stationary Dry Dock, recently completed at the ship yard of Messrs. Wm. Cramp & Sons in this city; the Hitchcock lamp for burning fat or greasy oils without chimneys.

The Secretary also made a Report of the progress being made by the "Penna. Museum and School of Industrial Art," as the representative of the Institute in Board of Trustees of that body.

The Secretary read a communication from the American Society of Civil Engineers, tendering to the Members of this Institute an invitation to visit and make use of its rooms in the west gallery of the Main Building at the Centennial Exhibition.

Mr. A. G. Buzby offered a plan for the rearrangement and classification of the awards (medals, &c.) of the Institute, which on motion was referred to the Committee on Sciences and the Arts.

Mr. Hector Orr offered a resolution, relating to the construction of a ship canal across the Isthmus of Panama, which, on motion of Prof. Houston, was laid on the table.

On motion, the meeting then adjourned.

J. B. Knight, *Secretary.*

SPRING PROPULSION FOR STREET CARRIAGES.*

By Edw. H. Leveaux.

The following description in the language of an amateur in mechanics will, I hope, give an idea of the car and its machinery as patented by me on the 24th of September, 1873, and of the progress towards perfecting and introducing the same to this time.

*From the *Journal of the Society of Arts*, May 12, 1876.

Some years back I was struck with the simplicity of the ordinary toy mouse, which by a few turns of a common watch key in the hands of paterfamilias gives so much pleasure to the younger members of his family; and it appeared to me, with an improved method of spring coiling and tempering, a carriage for passengers might be manufactured to run on the tramways and railways.

In application to the ordinary form of tramway carriage, I have utilized a portion of the space below the floor of the car for an arrangement of drums, or barrels, containing the springs, which may be placed transversely in two groups, or sets, suitably inter-connected so as to form one continuous volute, acting to generate revolutions of the driving wheel, and thus effect the propulsion of the car. At the terminal or intermediate stopping stations, the means of winding up and re-coiling the springs, are to be provided by a suitable fixed steam-engine, or other prime-motor, rotary motion being communicated by a shaft under the roadway to vertical spindles and geared wheels, which being thrown into temporary connection for the purpose with the spring barrels, will coil the springs until the requisite tension power is obtained.

Where the line is three or four miles in length, I shall require three engines; one at each end of the line, and one in the middle. Where stationary engines cannot be worked, it is my intention to employ portable engines, which can be brought to the winding-up barrels, and the process of winding gone through, during the collection of tickets and checking the number of passengers. I think it will be advisable that the places where these "wind-ups" occur should be stopping stations, where passengers may alight from or enter the carriages. These stopping-stations are quite the custom abroad, and it will facilitate the working of my spring-cars if adopted where my invention is used.

On country roads, where long distances have to be traversed, I propose using an auxiliary spring engine. This engine will be fitted with the most powerful springs we can obtain, with full reversing and brake power. At convenient sidings on the route, and where it is calculated the spring power under the car will be expended, one of these auxiliary engines will be attached, which will draw the car a considerable distance, where another may be in readiness to continue or finish the journey, as the case may be. Should it be desirable on

some lines to have several cars drawn at once, I am of opinion the auxiliary engine can be fitted with sufficient power to draw, at a moderate speed, several such light cars with passengers; but this is a matter for consideration after my system has had a fair trial on the public tramways, with the style of car at present in use.

I commenced operations about August, 1873, and after trying some experiments on a paper car, with ordinary watch springs, I took out my patent in September of that year. At that time the largest springs made, were used for the purpose of lifting "Clark's patent iron shutters," and were about 6 lbs. in weight, giving a maximum pull of about 120 lbs. On visiting Sheffield, and seeing several of the most important steel and spring makers, I was informed springs of almost any size might be made, but fresh machinery (and some of a very costly character) and furnaces, etc., would have to be constructed, and none felt inclined to take this risk. I was ultimately introduced to the managers of the Titanic Steel Works, who undertook to provide springs for a rough trial; finding, however, their plant was incapable of turning out the steel required, they handed the matter over to the Phœnix Bessemer Steel Company. Mr. Thomas Hampton, the enterprising managing director, called on me, saw my model, and after due consideration, he assured me that with practice, and after experiments were made as to the exact quality of the steel required, almost any kind of springs could be rolled and tempered, and he at once undertook the affair.

Early in 1874 large springs were tested, and the car propelled by them on a short line laid down at my engineer's in the Borough, but after many experiments it was found the original iron barrels, and the machinery altogether, were too heavy to warrant a public trial of the car; sufficient, however, had been done to show the great stride made in spring tempering since the date my patent was taken out. We had already obtained a few springs with sufficient power to propel on the short line at the works, a heavily built truck, containing the spring boxes and machinery.

It was rather an amusing scene, however, this first run. Several of the men at the works were kind enough to volunteer as passengers for the first ride, not thinking the machine would develop so much power. On starting, the clutch was removed, and off the truck went; it, however, to use the words in which the circumstance was reported

to me, "started off at a rapid speed, and struck a plank placed at the end of the line with such violence as to throw itself off the line," together with my unfortunate friends, the workmen, who had so kindly given their services for the first trial. They picked themselves up with much good humor, and soon assisted to replace the car, all present being pleased that the machine had shown itself of so lively a character; and feeling satisfied with such a power properly developed, a great future must be the result of these experiments.

After this trial, long and many vexatious delays occurred before I induced the well-known spring makers, Messrs. George Salter & Co., of West Bromwich, to take up the matter. They laid down fresh machinery, and built new furnaces, securing the experience of their best hands in coiling and tempering large springs, and I am happy to say with great success. During the year 1875 many sets of springs were made and fixed under the car, which about May last was taken to West Brompton, and tried on the line at the Lillie-bridge Railway Works. At one trial we carried about five tons seven cwt., including car, machinery and passengers, and at the rate of about seven miles an hour; but having only three barrels at work, instead of twenty-four, we only made a proportionate distance.

Our first run on the rails took place at Lillie-bridge Railway Works one Saturday afternoon. The truck with the machinery fixed had, after some difficulty, been placed on the line, wound up, and brought to the starting place. It was anything but a pretty affair to look at, painted an ugly iron color; with its peculiar looking spring barrels underneath and between the wheels, and its long iron brake handle sticking up at one end, a more nondescript looking locomotive had never before, I should think, made its *debut* on the railway. It evidently puzzled the workmen and people engaged on the line, as, although it was Saturday afternoon, and the workshcds closed, a number of men and boys remained for two or three hours to see what our ugly customer was intended to do; when they discovered a "run" was to take place, and passengers wanted, a rush was made to secure seats, or, as I should more correctly say, stands, for the conveyance was not fitted for passenger traffic. Some sixteen men were soon standing in the truck and holding on to each other ready for starting. At this moment I was much amused at the con-

duct of the engineer and stoker on an engine shunting a long coal train, who had been requested to clear part of the line for my experimental run. They were sorely perplexed at seeing the men standing on what appeared to them a coal truck in difficulties, but no sooner did they perceive it start off with its motley group, without any apparent driving machinery, than they jumped off their engine and ran after the spring-car, climbing on the back, and taking part in its first journey along the line; and a very merry journey we had on our mongrel-looking carriage, the men and boys laughing outright at the comical appearance of the whole affair, at the same time expressing their pleasure at witnessing this novel kind of propulsion. "Only think, Bill," says one, "this 'ere truck being drove along by watch-springs."

Nearly three years have been spent in ascertaining the best method of tempering springs, and determining the most useful method of coiling the steel for my purposes. The time, however, has been most usefully employed in trials on my models and the truck and full-sized car at West Brompton. During this period some hundreds of different sized springs have been made and tested, and I may now fairly say all seeming difficulties have been overcome.

My spring makers, Messrs. George Salter & Co., have just completed the springs and machinery for propelling a car to run either on the asphalte roads or the ordinary tramways. Two sets of wheels have been made, which can be changed as required for either mode of transit. The car has been built especially for this machinery, the barrels placed longitudinally under the carriage, and in two sets, which can be worked successively or simultaneously, as the case may require. The spring power can be shut off at any time during transit, so as to take advantage of the impetus given to the car, and can be immediately applied when needed; full brake power is provided, together with a reversing gear, which has been greatly improved since the experiments made at Lillie-bridge.

The following comparison between the car tried at West Brompton and the one under construction by Messrs. Geo. Salter & Co., will show the improvements made during the last few months both in spring power, and in the style of carriage to be used either on the ordinary tramways or asphalte roads:

The body of the car tried at West Brompton weighed about 23 cwt.	The body of the car now constructed weighs 4 cwt.
The springs each weighed 120 lbs.	The springs each weigh 85 lbs.
The springs were each 65 ft. long and 4½ inches broad.	The springs are each 38 ft. in length, and 4 inches broad.
And had a maximum pull of 950 lbs.	And have a maximum pull of 1600 lbs.
Giving (each spring) 4½ revolutions.	Giving each spring over 7 revolutions.
These springs required boxes of 22 inches diameter.	These springs require boxes of 14 inches in diameter.

Thus, it will be seen the new car is about one-sixth of the weight of the one experimented upon last year, while it is nearly double the power and revolutions in the springs, with one-third less weight in springs and machinery. The barrels being arranged longitudinally under the car, give more room for the action of the brake and reversing gear.

As regards the important item of cost of machinery for driving a car by my spring-motors, and the annual cost of working a car on any of the London tramways by horse-power, it is estimated the expense of the latter is about £750 per annum, which includes keep of 14 horses, wear and tear and loss of stock (which I hear is very great), harness, stablemen, veterinary charges, rent, etc.; whereas it will be seen from the following estimate, my car can be worked at less than one-third of this annual expense:

The machinery for each car (which it is estimated will last many years), about £200.	
Interest on this outlay at 10 per cent., ...	£ 20
Proposed royalty on each car using my invention, per annum	100
Wind-up steam apparatus divided among cars in one of the metropolitan tramways, say per annum, ...	50
To make up round numbers, may be added for repairs, lubricating, and wear and tear, per annum, ...	30
Total expense of each spring-car per annum, . .	£200
Against £750 per annum for horse traction.	

The price of the spring-motor (£200) is not carried forward into the yearly charges, as it will form part of the rolling-stock of the company. The "winding-up" is managed by a 5-horse power engine in about two minutes. Where the line is over three miles it will require three engines, which will be capable of winding up at least 200 cars daily.

Book Notices.

United States Patents.—Henry Howson, Solicitor of Patents, and Charles Howson, Attorney-at-Law. Porter and Coates, Philadelphia. 16mo., 164 pp.

This brief treatise of the law of patents, as established by legal decisions, is, notwithstanding its brevity, exceedingly thorough and full in all the bearings of the law upon the issuance, maintenance, and traffic in patents. Passing over the opinions set forth in the introductory chapter, where, although the statements of fact are beyond question, the conclusions therefrom express only the views of the writers, the succeeding chapters give the words of the statute, with explanatory comments based upon copious references to cases which have been adjudicated. It is as clearly and distinctly set forth, as the use and meaning of legal language will admit—to *whom* patents are granted, and to whom they are not granted; weighing all the possible conditions of individuals and of grants—for *what* patents are granted, and for what they are not granted; covering all subjects of invention, whether process, material, or principle, combination or improvement—how to obtain a patent, and what will prevent this purpose; giving all the forms and courses of procedure which will or can arise in the Patent office and Courts in the attempt to procure a patent—and completing the treatise by a consideration of interferences, re-issues, assignments, grants, licenses, infringements, etc. An excellent and copious index adds to the value of the book immensely. It is fair to state that many of the quoted decisions have not met the scrutiny of an appeal to the Supreme Court, and that some others which are quoted have been based upon a somewhat different statement of the case than they have been applied to in the text of this book, and some of them would properly be overruled by the first clear-headed judge; but all this belongs to the well-known uncertainty of the law. In any event this little book supplies a popular as well as a legal want in the knowledge of the operation of the patent laws, and is worthy of a place on the shelves of all lawyers, and should be owned by all who intelligently, for themselves, wish to become patentees; or who, being now patentees, desire to appreciate the rights and uncertainties of their property.

Practical Treatise on the Construction of Iron Highway Bridges. Alfred P. Boller, C.E. John Wiley & Sons, N. Y. For sale by Claxton, Remsen & Haffelfinger, Phila.

This unpretentious treatise is scarcely popular enough for the most general reader, but it is sufficiently so to answer the purpose of instruction to any interested one. To the town or country officer who

is called upon in any way to consider what are the requisites of bridge building, it cannot fail to impart a flood of the most useful information. There have been no failures so hopeless as those which have been made by the uneducated practical man in the erection of roofs and bridges when they have relied upon and been trusted for their own ingenuity and observations, with guesses of strength in place of computations. This book should be put in the hands of those who have the authorization of expenditures for bridges, and it would lead them to see for themselves that while the construction of a bridge is not only limited to a few practical styles which they can readily understand; the absolute requirements of strength of parts need the estimate of the engineer, as decidedly as in making a purchase or sale, the weighing of hay or measuring of wood is a necessity of trade. The work will go further in the hands of the local surveyor or district engineer than any treatise on bridge construction before written to satisfy him that special information and experienced practical knowledge in bridge engineering is essential in reconciling the antagonistic bids and claims of rival proposers, and lead him to seek professional assistance to share his responsibilities, and in this way alone it is a most valuable addition to our technical literature.

Proposed Continuation of the Experiments of the late Prof. Walt. R. Johnson on American Coals.—The National Academy of Science has prepared a memorial to Congress, asking for a continuation of these extremely valuable experiments, to be extended to the coals of the Mississippi, and those of the elevated country beyond, to the Pacific Coast. The principal plea of this memorial is in behalf of the national protection and the demands of the U. S. army and navy, but the secondary one, in the interest of manufactures and commerce, would present a much stronger claim upon the government. Fuel is the primary necessity of modern civilization—the basis of modern industry, and the development of the resources of the country by investigation, under national direction and authority, is an unquestionable duty of Congress. No one of the numerous publications in the way of statistics ever made by the authority of the United States has had a larger quotation, or been more practically useful in the arts and sciences, than this original Report of Prof. Johnson, and an equally well considered document which should embrace the *fuel* and the *fuel* resources of this country would be appreciated in all lands. It is to be trusted that this recommendation of the academy will be liberally responded to.

Civil and Mechanical Engineering.

CONTINUOUS GIRDERS AND DRAW SPANS.

By A. Jay DuBois, C. E., Ph. D., Prof. Civil and Mechanical Engineering, Lehigh University, Bethlehem, Pa.

In a very excellent and justly popular "Engineer's Pocket Book," (John C. Trautwine, the Civil Engineer's Pocket Book, 1872, p. 304), our attention has lately been called to the remark that "the strains upon a drawbridge are very complicated; and the designing and construction of such bridges when of large spans, should be entrusted to experts only." In Humber's "Strains in Girders," (New York, D. Van Nostrand, 1869), we also find the statement that "it would perhaps be impossible to give mathematically accurate formulæ for the moments of rupture in continuous beams with moving loads, that would be worth anything for practical application." This statement is supported by reference to a "well known author" (J. H. Latham, "Iron Bridges"), who has even pronounced the case "too complicated for investigation." The graphic constructions given by Humber in the work above alluded to, are themselves only applicable upon the supposition that the spans are so proportioned, that the moments at any pier due to two successive loaded spans are equal; a condition which cannot certainly be realized for moving loads. Again, in a more recent publication ("Graphical Method for the Analysis of Bridge Trusses," Greene, New York, D. Van Nostrand, 1875), we find that "the mathematical investigations are intricate, and the formulæ deduced troublesome in application," that "a partial solution of the problem by mathematical calculation is attended with considerable difficulty, and that a complete solution for the bending moments and shearing forces at every section under moving, partial and irregular loads, tasks the powers of the best mathematicians, and is well nigh impossible, on account of the complexity of the formulæ, so far as any practical application of them by the engineer is concerned."

Again, in a work entitled "Strength of Beams, Columns and Arches," by B. Baker, E. & F. N. Spon, 1870, we read on page 313,

"the determination of the exact mathematical value of the maximum strains occurring in continuous girders of three or more spans, when subject to a moving load, involves problems of almost hopeless intricacy. The most expert mathematicians would have to devote a month or more to the preliminary calculations for a very ordinary bridge, and the results deduced, would not, after all, be more reliable in practice than those arrived at by comparatively simple modes of investigation . . ."

The above remarks and quotations illustrate well the prevailing opinions upon this subject in England and this country, and with these opinions we venture to join issue at every point. The problem of the continuous girder, including of course the particular case of the draw span, is not only capable of "complete solution," but *has been solved* both graphically and analytically with a thoroughness and precision which leaves, at least in a practical point of view, nothing to be desired.

Clapeyron's famous "theorem of three moments" (1857) was long since extended by *Bresse*, *Winkler*, and others (1862), to single concentrated loads in any position. *Culmann* and *Mohr* (1866) have given us a complete graphical solution, and in the latest work of *Winkler* ("Theorie der Brücken," Wien, 1873), we find both solutions given side by side, while in the recent work of *Weyrauch*, ("Theorie der Trager," Leipzig, 1873), a book well worthy to close the long list of investigations upon the subject, we find a most complete and extended discussion and solution. Finally, in the pages of this magazine for March and April, 1875, will be found formulæ deduced by Mr. Merriman, of the Sheffield Scien. School of Yale College, than which, nothing more simple or comprehensive can be desired by the practical engineer and constructor.

It is not our purpose to give a history of the subject, or we might perhaps show that it is little to the credit of English or American authors that they have so long treated it with "judicious silence," and thus ignored one of the most important developments of the last decade in engineering practice. The importance of the theory of the continuous girder as applied to *draw spans*, will at least be generally admitted; and when our engineers shall have become convinced of the fact which has already been demonstrated and admitted by German engineers, that there is a saving of material in the continuous girder, *casteris paribus*, of from 25 to 30 per cent. usually, and even

reaching as high as, in extreme cases, 50 *per cent.*, it is possible that even the continuous girder itself may meet with more favor than at present. The objections of such, and they are not few, who are ready to assert that this saving is imaginary, are best met by referring them to the theory, which is at the bottom precisely the same as that which they accept and work with, in the case of the *common* girder. If its results are accepted in the latter case, as they are universally; if the simple girder comes out merely as a particular case of the more general continuous girder; they must either reform their own practice or accept the conclusion. There are others, and they also are not few, who not denying the "theoretical result," hold that it cannot be realized "in practice." To such, the questions seem pertinent, 1st, how do you know? Have you ever tried? 2d, do you know of those who have tried the question and decided it adversely? If the first questions fail to meet a response, the whole case turns on the second. If that also is unanswered, the whole subject remains open most certainly. In this country the first question must remain unanswered. In the work of Winkler, above referred to, however, may be found a list of nearly a hundred continuous girders *actually erected* in Spain, England, Austria, Prussia, Switzerland, France, Italy, etc., of all spans, from 500 feet down, and all numbers of spans, from six down. Now the decision of those who *have* thus fairly tested the question is favorable, and the construction of such girders still goes on. Would it not be well then for those who boldly deny the possibility of such constructions, or their advantages, either theoretically or practically, to first inform themselves upon the theory they thus condemn, and the practice they thus oppose? Should theory alone indicate an advantage which in practice is only imperfectly realized, it ought, one would suppose, to be, if anything, an incentive to a nation not generally considered as deficient in inventive genius, and whose record, especially in bridge construction, during its early stages, is still an example of what may be done with imperfect materials, to obtain in practice the gain which theory indicates. At least, one would suppose that when others have successfully met the difficulty, such a nation would not be found very far behind. At present, it stands as a fact, that in nearly every civilized country, America excepted, the continuous girder has been investigated, erected, tried, and accepted, while American engineers still wisely shake their heads, doubt, and decline to try.

The influence of the work of *Weyrauch*, above quoted, is already to be seen in this country in the treatise by *Clemens Herschel* upon "Continuous Revolving Draw Bridges," (Boston, Little, Brown & Co., 1875). Finally, in this JOURNAL, for March and April, we may notice an article upon continuous girders by *Mansfield Merriman*, giving formulæ of the highest importance for the practical solution of the problem. Merriman's formulæ apply to any number of spans of any lengths, for uniform load over any single span, or for single concentrated load in any one span, and are so compact that everything necessary for the complete solution of the continuous girder may be entered upon a couple of pages of the note book. The calculation then proceeds in a manner precisely similar to that for the simple girder; which last is indeed but a particular case of the more general formulæ.

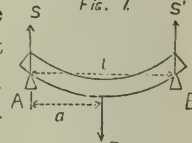
As to the difficulty of solution: if ability to calculate a continuous girder or draw span constitutes an "expert," we venture to hope that the perusal of these pages will put the reader in full possession of such a desirable accomplishment.

We shall first indicate the general nature of the problem required to be solved; what quantities are unknown and must be found, and how these quantities are then made use of. We shall then give a concrete example illustrating the above, assuming that we know what the desired quantities are; and, lastly, we shall give the formulæ of Mr. Merriman, by which these desired quantities may themselves be found. A few remarks upon the relative advantages and disadvantages of the continuous girder will then close our discussion.

II.—GENERAL NATURE OF THE PROBLEM.

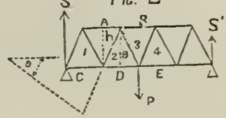
If a girder simply rests at its two ends upon supports, and is acted upon by any weight or weights, as in Fig. 1, we know that the weight P causes "*reactions*" at the ends, that is a *shear* S just to the right of the left support, and a shear S' just to left of right support. Now, these forces, viz., the weight and the end "reactions," are *all* the outer forces which act upon the girder. These outer forces being necessarily in equilibrium, because otherwise there would be motion, we can find S and S' by moments about A and B, or by the "law of the lever." Thus, if a is the distance of weight P from left end, and l is the length of beam, we

Fig. 1.



have, by the "law of the lever," $S \times l = P\,(l - a\,)$, and $S' \times l = P\,a$ or $S = \frac{P(l-a)}{l}$ and $S' = \frac{Pa}{l}$. Now, in any framed structure whatever, when once *all* the outer forces are known, the strain in any and every piece can easily be found by moments. Thus, Fig. 2: let the height of truss be h, and panel length $\frac{l}{4}$, or one-fourth of the entire length. Now, we can find the strain in *any* piece whatever, by supposing the structure cut entirely through by a plane which cuts only three pieces, the strains in which are unknown, and in order to determine the strain in any one of these pieces, *take the intersection of the other two* as a centre of moments. Thus, suppose A, 2 and D cut. Then, to determine A, take the centre of moments at the intersection of 2 and D, the other two pieces. We have then str. in $A \times h = S \times \frac{l}{4}$ or str. in $A = \frac{Sl}{4h}$. Again, str. in $D \times h = -\,S \times \frac{3}{8}\,l$, or str. in $D = \frac{3\,S\,l}{8\,h}$, tension being considered minus, and compression plus, and rotation, which would cause tension, being minus; and so on, for any flange, not forgetting to take into account the weight P when we pass it. Thus, str. in $E \times h = -\,S \times \frac{5}{8}\,l + P \times \frac{1}{8}\,l = -\,\frac{5\,l\,S}{8} + \frac{Pl}{8}$; or str. in $E = \frac{P\,l - 5\,l\,S}{8\,h}$, the centre of moments being always at the intersection of the *other two pieces* cut, viz. here, 4 and B; or, what is the same thing, we may take str. in $E \times h = -\,S' \times \frac{3}{8}\,l$, or str. in $E = \frac{3\,l\,S'}{8}$, thus leaving out P by taking the other reaction. Any single moment which tends by itself to cause tension in a piece, may be put down with minus sign, if compression, with plus sign. The method is precisely the same for a diagonal. Thus, for diagonal 2, the intersection of *the other two pieces*, viz., A and D, is here at an infinite distance, since A and D are parallel.* Taking

FIG. 2



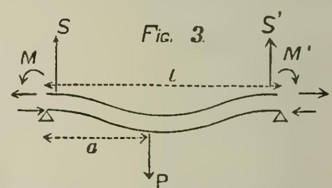
* If A and D are not parallel, their intersection is the centre of moments for the diagonal, with reference to which the moments of 2 and S must balance, just as above, for the infinitely distant point.

this point, then, as a centre of moments, we have, since the lever arm of 2 is $\infty \cos \theta$, where θ is the angle which the diagonal makes with the vertical; $S \times \infty =$ str. in $2 \times \infty \cos \theta$, or str. in 2 $= \frac{\infty S}{\infty \cos \theta} = S \sec. \theta$, since $\frac{1}{\cos} =$ sec. and ∞ cancels out. Hence, the well known rule for parallel flanges, "multiply the shear by the secant of the angle which the diagonal makes with the vertical." If the diagonal were on the other side of the weight, we should have S' sec. θ or $(P—S)$ sec. θ. That is, the *shear is always the algebraic sum of all the forces between the point considered and the end.* If it acts up at the foot of a diagonal, or down at the top, it causes compression, otherwise tension. Thus, we see that all we need to know in order to calculate completely the strains in every piece, due to each and every weight, are the *outer forces.* These once known, the problem is one of simple multiplication. Such are, in brief, the principles by which we may calculate any simple truss of single span. Now, for a *continuous girder*, the principles are precisely the same, and their application precisely the same, and no more difficult, *provided that in this case also we know all the outer forces.*

Let us, therefore, consider what *are* in this case the outer forces; and how does this case then differ from the preceding.

If Fig. 3 represents one span of a continuous girder, which sustains a weight P at a distance a from the left end, we have, just as in Fig. 1, of course, two reactions or *shears* S and S' at the supports, which are, in general, different numerically from those obtained in the first case, and *in addition* at each end a *pair* of forces, *or couple* acting to cause tension in the upper fibre and compression in the lower at the supports. Owing to this couple, we have then at the supports not only the shears, S and S', *but also two moments*, M and M'. These moments we always consider positive when tending, as in the figure, to cause compression in *lower flange*, or fibre, otherwise negative. That is, we take the *lower* flange as a flange of reference, and consider compression as plus and tension as minus. These moments, then, divided by the depth of the truss, or the lever arm of the forces, will, of course, give the intensities of the forces themselves, acting in the upper and lower flanges. If the moment is positive, these forces

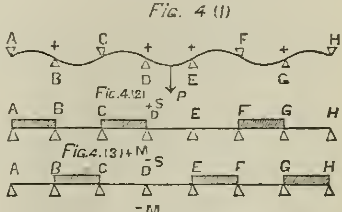
FIG. 3.



act as shown in Fig. 3, so as to cause compression in lower flange at supports and tension in upper. If the moments are negative, these forces are respectively reversed in direction, so as to cause tension in lower flange at supports and compression in upper. The shears are positive if acting upwards, negative downwards. Now, these are *all* the outer forces acting upon the truss, and *if we can only find what they are*, precisely the same principles which held good for Fig. 2, hold good here also, and no more difficulty need be experienced for the one case than for the other. So far as loads in any one span are concerned, then, we simply have to find, and it suffices to know, what are the shears and moments due to a single load placed anywhere in that span. If we know them, we can easily find by moments the strains in every piece due to each apex load, and a tabulation of these will then give us at once the strains due to uniform dead load, and to moving load. Formulæ, then, which enable us to find the above quantities by simple insertion of the numerical values for any particular case, are all that we need for a load in any one span. Such formulæ we shall give hereafter.

But these do not solve the *whole* case. Loads *exterior* to any one given span, *i.e.*, situated in *other* spans, have also an influence and cause strains in the pieces of the span, the strains in whose pieces are required. The above formulæ, then, would only enable us to find the strains due to what we may call "*interior loading*," or loads in the span itself. We have now to consider the effect of "*exterior loading*," or loads in other spans, and the influence they have upon the pieces in the particular span, the maximum strains in which are required. Let us take, for instance, a girder of seven spans, as shown in Fig. 4 (1), and consider the action of a load in D E, the middle span.

Fig. 4 (1)



Now we easily see at once, that *both the moments and shears at the two supports of any loaded span must always be positive*, that is, there must always be compression in lower flanges, just over the end supports, and the shears there must act up, or opposed to the load. Now, if no other span is loaded, and if all the supports are on level, and the girder must touch every support, it must take a wavy line, such as shown in the Fig., and supports C and F must be above, B and G below, A and H again above

the girder. In general, then, *the moments and shears at the two ends of any loaded span are always positive ; right and left from these two ends they alternate in sign.*

Now let us apply these principles to the span $D\ E$, the maximum strains in the pieces of which are required. First, considering each apex load in the span $D\ E$ itself, that is the "*interior loading*" of the span, we are supposed from our formulæ to have first found the shear and moment (both positive) at the support D for each individual apex load. We can then, by the method referred to, in connection with Fig. 2, find the strains in each piece due to each of these weights, and tabulate them. We now come to consider "*exterior loading*." For this purpose we wish, first, the greatest *positive* moment and shear at the same support D, due to exterior loads alone; and, second, the greatest *negative* moment and shear at D, due to exterior loads alone. We must find and tabulate the strains due to these two cases also by themselves, and the span is solved. Now, from our principles above, for these two cases, we reason as follows. Every load in $A\ B$, Fig. 4 (2), causes positive moments and shears at A and B, and then at the other supports the moment and shear alternate in sign. Thus, a *full* load over $A\ B$, as shown in Fig. 4 (2), gives a positive moment and shear at B and D. A load over $B\ C$ gives a negative moment and shear at D; over $C\ D$, positive again at D. We skip the span $D\ E$ itself—the "interior loading" applies to that—and go on to $E\ F$, a load over which gives negative moment at D, while over $F\ G$ we have positive, and over $G\ H$ negative moments, and shears at D. The case of loading represented in Fig. 4 (2), then, in which $A\ B$, $C\ D$, and $F\ G$, are fully loaded and the others unloaded, will give the greatest positive moment and shear which can possibly occur at D for exterior loading, and hence the greatest strains; while the case represented in Fig. 4 (3) gives the maximum negative moment and shear at D, and hence the greatest strains for that case. We must now find and tabulate the strains for these *three* cases, viz., "interior loading" strains, and the two cases of "exterior loading" strains. Now, if we know the *ratio* of dead to live load, then, by adding algebraically the strains thus found, and multiplying by this ratio the algebraic sum, we have a column for *dead load over the whole girder, from end to end.* We can now easily pick out the maximum strains which can ever occur, and determine what pieces must be counterbraced, and how much the strains are in each case.

In order to do all this, it will be observed that the *method* is precisely the same as for a girder of single span, and its application, though perhaps a little longer, no more difficult. We only need to know the outer forces. With these we work.

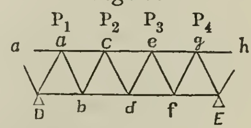
We see therefore at once what it is that our formulæ *must* do, and all that is necessary that they *should* do. They should enable us to determine for any number of spans of any lengths over level supports, first, the moment and shear at the end of any given span for a single weight placed anywhere *in that span*, second, the moment and shear at the end of that span for a uniform load over the whole of *any other span.* This is just what our formulæ, which we shall give hereafter, enable us to do, and although they also enable us to solve many other questions connected with the continuous girder incidentally, such as deflection, points of inflection, etc., the above is all that it is essential that we should know for full and accurate solution.

Before giving these formulæ, we shall now give briefly an example, illustrating the above, supposing that the moments and shears as found by the formulæ are known.

III. CONTINUOUS GIRDER.—EXAMPLE.

Let us take for example a girder of seven equal spans, and seek the maximum strains which can ever occur in the middle span $D\,E$, Fig. 5.

Fig. 5.



Let the length be 80 ft., divided into 4 panels of 20 ft. each, and let the live load be 2 tons per ft. or 40 tons at each upper apex, the uniform dead load being only $\frac{1}{2}$ as much, or 20 tons per upper apex. Height of truss, 10 ft.

Now the quantities, which for the present we must suppose known, and which are given by our formulæ, are as follows :

Positive moment at D [1st system of exterior loading, Fig. 4 (2)], $= +\ 788{\cdot}2$ ft. tons, corresponding shear at right of $D = +\ 14{\cdot}63$ tons.

Negative moment at D [2d system of exterior loading, Fig 4 (3)], $=$ $-382{\cdot}54$ ft. tons, corresponding shear $= -\ 14{\cdot}63$ tons.

Also for the interior loads in the span itself, we have :

For the first load P_1, moment at D	$= +\ 158{\cdot}92$,	shear	$= +\ 36{\cdot}17$
" " second " P_2, "	$= +\ 271{\cdot}96$,	"	$= +\ 25{\cdot}88$
" " third " P_3, "	$= +\ 203{\cdot}36$,	"	$= +\ 14{\cdot}16$
" " fourth " P_4, "	$= +\ 62{\cdot}88$,	"	$= +\ 3{\cdot}82$

These are all the data, which we need to know. The calculation now proceeds just as for a simple girder.

Thus the strain in the first end flange, $a\ a$, above D, is equal to the moment at D divided by height of truss. If the moment is positive it indicates compression in lower or tension in upper flange. Thus for first case of exterior loading we have in this flange $\frac{788{\cdot}2}{10}$ $= 78{\cdot}8$ tension, since the flange is here an upper one. For the second case of exterior loading $\frac{382{\cdot}54}{10} = 38{\cdot}2$ tons compression. For interior loading, we have for P_1, 15·8 tons tension, and for P_2, 27·2, for P_3, 20·4, and for P_4, 6·4 tons, all tension likewise. In the first case of exterior loading also, the moment at $D = +\ 788{\cdot}2$, and the shear $S = +\ 14{\cdot}63$, cause strains in all the other pieces, which we can readily calculate. Thus, for instance, for this first case,

str. in $c\ e \times 10 = -\ 788{\cdot}2 + 14{\cdot}63 \times 40$ or str. in $c\ e = -$ 20·3 tons, the centre of moments being at d, and tension being minus, also

str. in $d\ f \times 10 = +\ 788{\cdot}2 - 14{\cdot}63 \times 50$ or str. in $d\ f = +$ 5·6 tons, the centre of moments being at e. A positive moment always gives compression in lower flange, tension in upper. Again, str. in diagonal $D\ a = S \times \sec. 45° = +\ 14{\cdot}63 \times 1{\cdot}414 = +\ 20{\cdot}7$ tons.

$ab = -\ 20{\cdot}7$, $b\ c = +\ 20{\cdot}7$, and so on alternating in sign, a positive shear acting up, and causing compression when acting up at the foot or down at the top of a diagonal.

The strain in any flange is thus easily obtained by a simple equation of moments, by supposing that flange cut and the point of rotation at the opposite apex, or intersection of the other two pieces, and then taking the moments of all the outer forces to the left of the section about this point, and finding the force which must act in the cut flange, in order to prevent rotation. For fuller explanation of this method of moments, see the author's "Elements of Graphical Statics," Wiley and Sons, New York; also his article in the April number of this JOURNAL upon the "Graphical and Analytical Determination of Strains in a Roof Truss."

In similar manner we can find the strains in every piece, due to the second case of exterior loading. Thus,

str. in $c\ e \times 10 = +\ 382{\cdot}54 - 14{\cdot}63 \times 40$ or str. in $ce = -\ 20{\cdot}3$ tons

str. in $d\ f \times 10 = -\ 382{\cdot}54 + 14{\cdot}63 \times 50$ or str. in $df = +\ 34{\cdot}9$ tons

str. in diagonal $D\ a = -\ 14{\cdot}63 \times 1{\cdot}414 = -\ 20{\cdot}7$ tons.

$a\ b = +\ 20{\cdot}7$ $b\ c = -\ 20{\cdot}7$, etc.

So also in precisely similar manner, for each *interior* weight P_1, P_2, etc., we can find the strains. Thus take for instance P_1. For this weight we have the moment at $D = +\ 158{\cdot}92$, and shear $= +\ 36{\cdot}17$. Then the strain in first end flange *a a*, above D, is $\frac{-158{\cdot}92}{10} = -\ 15{\cdot}8$ tons (tension is always *minus*), and str. in $D\ b \times 10 = +\ 158{\cdot}92 - 36{\cdot}17 \times 10$ or $D\ b = -\ 20{\cdot}3$ tons; str. in $a\ c \times 10 = -\ 158{\cdot}92 + 36{\cdot}17 \times 20 - P_1 \times 10$, or since $P_1 = 40$ tons, str. in $a\ c = +\ 16{\cdot}4$ tons. Observe that for this piece the weight P_1, also comes into the equation. Again, str. in $b\ d \times 10 = +\ 158{\cdot}92 - 36{\cdot}17 \times 30 + P_1 \times 20$ or $b\ d = -\ 12{\cdot}6$ tons, and so on for every flange. For the diagonals, str. in D a $= S \times$ sec. $45° = 36{\cdot}17 \times 1{\cdot}414 = +\ 51$ tons. For diagonal *a b*, by reason of the weight $P_1 = 40$ which acts down at *a*, the shear is $-\ 40 + 36{\cdot}17 = -\ 3{\cdot}83$ tons, which, since the weight preponderates, acts down, and hence causes compression on *a b* also, of $3{\cdot}83 \times 1{\cdot}414 = +\ 5{\cdot}41$ tons, $b\ c = -\ 5{\cdot}4$, $c\ d = +\ 5{\cdot}4$, and so on alternately plus and minus for the rest. Thus we proceed for each weight, and can thus fill out the following table.

1	2	3	4	5	6	7	8	9	10	11	12
Flanges.	Interior loads.				Interior loading. Maximum strains.		Exterior loading.		Dead load = ½ live.	Total maximum strains.	
	P_1	P_2	P_3	P_4	Tens. −	Comp. +	1st Case.	2d Case.		Tens. −	Comp +
a a	−15·6	−27·2	−20·4	−6·4	−69·6	......	−78·8	+38·2	−55·1	203·5	....
a c	+16·4	+24·4	+8·0	+1·2	......	+50·0	−49·5	+8·9	+4·7	44·8	63·6
c e	+8·8	+36·4	+36·4	+8·8	......	+90·4	−20·3	−20·3	+24·9	15·7	115·3
e g	+1·2	+8·0	+24·4	+16·4	......	+50·0	+8·9	−49·5	+4·7	44·8	63·6
g h	−6·4	−20·4	−27·2	−15·6	−69·6	......	+38·2	−78·8	−55·1	203·5	......
D b	−20·4	+1·2	+6·0	+2·8	−20·4	+10·0	+64·2	−23·6	+15·1	28·9	89·3
b d	−12·8	−50·8	−22·0	−5·2	−90·8	......	+34·9	+5·6	−25·1	115·9	15·4
d f	−5·2	−22·0	−50·8	−12·8	−90·8	......	+5·6	+34·9	−25·1	115·9	15·4
f E	+2·8	+6·0	+1·2	−20·4	−20·4	+10·0	−23·6	+64·2	+15·1	28·9	89·3

We give in the table, in order to economize space, only the flanges; the method is precisely the same for diagonals also, but for the purpose of illustration a few of our results are sufficient.

Having found, and tabulated the strains due to each weight, as shown by the first 5 columns for interior loading, we add all the tensions and compressions for each piece, and place the results in columns 6 and 7. We thus have the "maximum strains" which can be caused by the interior loads alone in the span $D\ E$. In the next two columns, 8 and 9, we now place the strains due to the two cases of "exterior loading" [Fig. 4 (2) and (3)]. Now if the uniform dead load is known to be any ratio of the live, as say $\frac{1}{2}$, we have only to take the algebraic sum of the strains in columns 6, 7, 8, and 9, horizontally, and put one-half this sum in column 10. We thus find column 10 for dead load. Finally, from columns 6, 7, 8, 9, and 10, we can find the *total maximum strains*, which can possibly occur, as given in the last two columns, 11 and 12. Thus, take for instance, the piece $a\ c$. In this flange there is a constant compression due to the dead load of 4·7 tons. The second system of loading, if it should ever occur, which, if not probable, is at least possible, would add to this, 8·9 tons, while interior loading may at the same time independently cause 50 tons, all compression. Since all three cases *may* exist together, we have $4{\cdot}7 + 8{\cdot}9 + 50 = 63{\cdot}6$ tons compression in $a\ c$. But again, the *first* system of exterior loading, which may also act alone, causes 49·5 tons tension in $a\ c$. Diminishing this by 4·7 tons compression, due to dead load, which must always act, we have $-49{\cdot}5 + 4{\cdot}7 = -44{\cdot}8$ tons tension in $a\ c$. These two strains are the greatest which can ever occur in this piece. We see also that this piece must be counterbraced, because the tension $-49{\cdot}5$ for first case, is *greater* than the constant compression of 4·7 due to dead load, while on the other hand $g\ h$ need not be counterbraced, because the greatest compression which can ever occur, viz., 38·2, is *less* than the constant tension 55·1 due to dead load. So also for $a\ a$. Since in this case we have taken a middle span, observe that the strains for P_1 and P_4, P_3 and P_2, are similar, as they should be. Thus, strain in $a\ a$ due to P_4 is the same as in $g\ h$ due to P_1, and so on.

Thus we see that the method of calculation is precisely the same as for a girder of single span. In this latter case, columns 8 and 9 would of course fall out; also, since there are no end moments, and

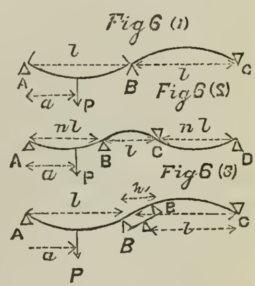
since the end shears are different, the numerical values of the strains in columns 2 to 5 will be different.

In any framed structure whatever, then, it will be seen that the sole difficulty is in finding all the *outer forces* for any desired loading, and that generally the repetition of a single load covers all cases of moving, or live and dead load.

The outer forces, such as end moments and shears, being once known, the rest is easy. In the author's work, entitled the "ELEMENTS OF GRAPHICAL STATICS," *Wiley and Sons*, New York, will be found many examples in illustration of the above, together with easy and practical methods of finding the outer forces for continuous girders, pivot spans, braced arches, suspension trusses, and all the various forms of girders and roof trusses, which occur in engineering practice, together with the methods of calculation and diagram.

IV. THE PIVOT OR DRAW SPAN.

The method of calculating the strains in a pivot span presents no difficulty, provided, as always, we know the shears at the supports for a weight anywhere. The pivot span may be considered as a girder, continuous over three supports, or in some cases, over four supports, the small intermediate span being the width of the turn table. In this latter case, again, it may happen that both the centre supports are pivoted upon a third, so that they can *tip* under the action of a weight, one down and the other up. In Fig. 6 we have these three cases. The two first are, of course, only particular cases of our general formulæ, which we shall give hereafter. The third was first noticed, and the formulæ for the "reactions" at supports first given by Clemens Herschel, (Continuous revolving draw spans, Little, Brown & Co , Boston). Of course, in any case, for an *end* support; "reaction" is the same as *shear*, since there is no other span beyond, to contribute its pressure to the support. But in general, at any support, the reaction is the *sum of the shears on each side.* They are shears which our formulæ give, and they should *never* be confounded with "reaction."



Now in the case of the pivot span, it is evident that if the shear at *A*, due to a weight placed anywhere in any span is known, then, since

at this support there is no end moment, we have all we need, in order to find the strains in every piece of the span $A\ B$. The strains in the other end span will, of course, be the same, if, as is nearly always the case, the two are of the same length; if not, they can be calculated for the second, as for the first. The middle span, if any, when it rests directly upon the turn table, can be disregarded; otherwise it is calculated precisely as for a span of a continuous girder, already illustrated.

The centre support should be *raised above the level of the ends by precisely the amount that the draw when open deflects;* otherwise, when once opened it would evidently be difficult to shut it again.

The dead load strains, then, are found for draw open, and these same strains exist unchanged, even when the draw is shut. The live loads only are to be considered, each by itself, for draw shut, and the fact that the centre support is thus raised, *will not affect the shears as given by our formulæ.* This fact was first pointed out by Clemens Herschel in his work above referred to, and the proof of it may be found in the author's "Graphical Statics." Moreover, it is not necessary to enter into elaborate computations, as to the precise amount by which the centre support must be thus raised; it is only necessary in practice, to raise the centre support till the ends just bear and no more.

We have then two calculations to make, one for draw open and strains due to dead load; the other for draw shut and strains due to live load; the union of the two gives us the maximum strain in any piece. In order to make the latter calculations, we have simply to find the reaction (shear) at end support, for each and every apex load in all the spans (generally omitting centre span, which rests directly upon the turn table). Although the formulæ, which we need, therefore, are merely special cases of more general formulæ, which we shall presently give; still the case of the draw is so important that we shall give here the special formulæ required.

Let the load P be at a distance a from the left support A, then we have for *two equal spans*, $l = A\ B = B\ C$, Fig. 6, for the *reactions* at the supports A, B and C;

$$R_A = \frac{P}{4l^3}\ (4\ l^3 - 5\ l^2\ a + a^3).$$

$$R_B = \frac{P}{2l^3}\ (3\ l^2\ a - a^3).$$

$$R_C = \frac{P}{4l^3}\,(a^3 - l^2\,a).$$

Remember, that the shear at *ends* is the same as reaction, but the middle "reaction" is the *sum* of the shears on each side of of the middle support. For load in other span we can use the same formulæ. Thus reaction at A for load in $B\ C$ is same as at C for similarly placed load in $A\ B$, etc. These reactions add up equal to the load P, as should be.

For the second case of four fixed supports, Fig. 6, we have for a load P in the left end span $A\ B$, at a distance a from the left support A, the *end* spans being $n\,l$ and the centre span $B\ C = l$, the following formulæ for reactions.

We put the ratio of the distance a to the length of span $n\,l$, or $\frac{a}{n\,l} = k$ and represent a quantity of frequent occurrence by H, viz. $H = 3 + 8\,n + 4\,n^2$. Then

$$R_A = \frac{P}{H}\,[H - (H + 2\,n + 2\,n^2)\,k + (2\,n + 2\,n^2)\,k^3].$$

$$R_B = \frac{P}{H}\,[(3 + 10\,n + 9\,n^2 + 2\,n^3)\,k - (2\,n + 5\,n^2 + 2\,n^3)\,k^3].$$

$$R_C = \frac{P}{H}\,[-(n + 3\,n^2 + 2\,n^3)\,k + (n + 3\,n^2 + 2\,n^3)\,k^3].$$

$$R_D = \frac{P}{H}\,[n\,k - n\,k^3].$$

These reactions should add up equal to the weight. They are all we need, as loads in the centre span $B\ C$ can be disregarded, and in the right end span the same formulæ apply, only we have to put R_D in the place of R_A, R_C in place of R_B, etc., and take a from D towards the left, instead of from A towards the right.

For the third case, or the *tipper*, we take for the sake of distinction, the *middle* span, equal to $n\,l$, and the two outer ones each l. We have k then equal to $\frac{a}{l}$, and we now put $H = 4 + 8\,n + 3\,n^2$. The reactions are now therefore*

$$R_A = \frac{P}{2H}\,[2\,H - (10 + 15\,n + 3\,n^2)\,k + (2 + n)\,k^3].$$

$$R_B = R_B = \frac{P}{2H}\,[(6 + 9\,n + 3\,n^2)\,k - (2 + n)\,k^3].$$

* For demonstrations of these formulæ see author's Elements of Graphical Statics.

$$R_C = \frac{P}{2H}\left[(2+n)\,k^3 - (2+3\,n+3\,n^2)\,k\right].$$

These reactions when added together, $R_A + 2\,R_B + R_C$, are equal to P, as should be. By the application of these formulæ, which for any particular case are by no means intricate, we can find the reaction at A for every apex load, and can then calculate the strains in each piece of the span $A\ B$ for each and every load. A negative reaction in any case, indicates that the support must be above, and unless more than counterbalanced by the dead load, the girder will rise off the support if under, unless latched down.

The above comprises all that need be said under this head; we shall now give an example illustrative of the above, and then pass on to the general formulæ so often referred to, by means of which we can in any case, for any number of spans, find the moments and shears at any support.

(To be continued.)

GAS WORKS ENGINEERING.

By Robert Briggs, C. E.

[Continued from Vol. ci, page 301.]

"Most of the sulphur distilled from the coal passes over with the ammoniacal liquor, and the authorities vary considerably as to the quantity present in crude gas. But, taking the weight of a cubic foot of crude gas, at the temparature of sixty degrees Fahrenheit, with the density of fourteen-candle gas, as equalling two hundred and thirty grains, and two-tenths of one per cent. as the weight of sulphur, there would be four and six-tenths grains of sulphur per cubic foot; while the standard for excellence is (as has been stated, twenty grains per hundred feet) two-tenths grains per cubic foot; showing that only one twenty-third the sulphur which existed in crude gas, is tolerated in purified gas. When gas, either crude or purified, is burned, all the compounds are reorganized in the products of combustion; the sulphur compounds are decomposed, the sulphur itself going to form, with oxygen, sulphurous acid; the ammonia compounds resolve into nitrogen and hydrogen, the latter going to form,

with oxygen, water; but it is possible that a little nitric acid may form in the process of incomplete combustion. The sulphurous acid, also, probably transforms itself in the air into sulphuric acid. At all events, the effect of sulphur in gas, even when reduced to very small amounts, approximating in quantity to the standard accepted by English law, is very perceptible upon colors of fabrics, paints, leather, etc., and especially perceptible to the occupants of rooms in which many burners are used. A sensation, not so much of smell, but of dryness and acridity in the nostrils and throat, accompanied with a binding feeling in the forehead, is recognized as the indication of bad gas; and immediately complaint follows when imperfect purification has occurred.

"In the history of the manufacture of gas, it appears that the earliest difficulty encountered was this defect of crude gas; and the necessity of removal of sulphur at once engaged the attention of the first gas-makers. These gas-makers were not chemists, and the science of chemistry had scarcely then, in 1800–10, reached the point to designate what was required to effect the purpose,—it was consequently a mere trial of various substances.

"Washing with water was first resorted to, and after a time lime-water was substituted in the hope that it might answer. The use of lime-water proved very satisfactory, and up to the present time no material of cheap or ready application has been found so efficient and satisfactory in result, although it will be seen that it has some troubles in the disposition of the spent lime-water, in the gas-works themselves, that have so far proved insuperable.

"The ammonium compounds, when present in gas, are less harmful to the consumer, but they destroy the grease of the gas-cocks, injure the burner-tips, rust away and eat up the material of gas-meters, occasion deposits of very offensive liquors which sometimes escape, and they impair materially the illuminating quality of the gas.

"The naphthaline passes off with the gas from the retort as a vapor (probably other hydro-carbons of nearly the same constitution accompany what the gas-maker knows as naphthaline). It is one of the few hydro-carbons which isolate themselves positively in the process of destructive distillation of coal, and at ordinary temperatures is seen as a fine white crystalline mass, in which form it condenses and deposits as the gas is cooled. Crude coal tar has a large quantity dissolved in its oils, which is separated by heat, between the light and heavy

oils. It is believed, however, that crude coal tar will absorb it all (or nearly all) if the tar is allowed to remain, and be brought in contact with the gas until quite cold; but as the tar also absorbs all the gaseous illuminants in this way, this process is not available. Naphthaline occasions stoppage of the pipes in cold weather, and is a source of great trouble to some gas-works, where the condensation is not slow enough to separate it. It is freely dissolved and absorbed by gaseous hydro-carbons (the luminant gases), and when it occurs in pipes can be removed by use of very *rich* gas for a time. It is a luminant itself, and can only be classed with the impurities, because it must be removed to certain limits of quantity (varying with certain seasons of the year) to admit of the service and distribution of gas.

"Naphthaline has a pungent, distinctive odor, which disseminates to great distances when any of the vapor is allowed to escape. It is probably the *vehicle* of other smells from coal gas, as musk is made to convey some perfumes. Naphthaline resembles camphor in many ways.

" The non-burning substances are not injurious, only that their presence in any proportion reduces the luminous efficiency of gas, to a far greater extent than is due to the quantity present. A very little air or carbonic acid will reduce the light of a fourteen-candle burner to that of seven candles. One per cent. of carbonic acid is said to impair the light five per cent., and six per cent. of air to impair it fifty per cent. The air accompanying any gas, comes from changing the purifiers at the works, and similar admissions; but carbonic acid is one of the products of distillation.

"Of all these compounds of the gas, but very few are positively poisonous. Sulphuretted hydrogen (mainly), and carbonic oxide (in a less degree), are the most abundant and dangerous by themselves. Some of the ammonium compounds would be equally noxious if they were isolated, and if sufficient quantities were dispersed in any locality; but, as before stated, complete combustion reduces all these products to comparative harmlessness.

"In the burning of a gas-flame, the burning substances appear to be employed in establishing such a heat as shall cause the particles of carbon in the luminants to become incandescent, and the light is assumed to proceed from these particles, which are intensely heated and isolated from oxygen (air), so that they do not burn at that instant; the further progress of combustion is the burning of these

particles, so that they will be made into carbonic acid, and not be disseminated as smoke. If the heat is not intense enough they may never become incandescent or luminous, but merely separate from their vehicle (the hydro-carbon), and pass off as smoke altogether.

["The chemical composition of purified gas, of 16 candles burning power, is nearly as follows, per hundred parts: Hydrogen, H_2 44 to 48; Marsh gas, $C\ H_4$ 34 to 38; Olefiant gas, $C_2\ H_4$ and other hydro-carbons, etc., 6 to 8; carbonic oxide $C\ O$, 5 to 7; carbonic acid $C\ O_2$, 1 to 3; air $N_2\ O$, 1 to 3, aqueous vapor $H_2\ O$ (to saturation, 40° to 60°), 1 to 2. The specific gravity of coal gas of the assumed quality, that is, the weight of a given volume as compared to that of air at the same temperature and pressure is 0·430; and this gives the volume of a pound of gas at 70° to be 31·4 cubic feet, when the volume of a pound of air is 13·5 cubic feet (neglecting fractions, in both cases, too small to be of consequence for the purpose of the present estimates).

"Taking the average of the constituents of coal gas, they can be reduced to 53 parts of hydrogen, 34 parts of carbon, 6 parts of carbonic oxide, which are combustible; leaving 5 parts of non-combustible substances.

"For the burning of a cubic foot of gas there will be required all the oxygen which exists in two cubic feet of air; but in order to *effect* complete combustion, at least twice this volume of air must be provided, or must accompany the burning.

"When *a*, a burner of average size of 4½ cubic feet per hour will need 90 cubic feet of air in the same time, or 1½ cubic feet of air per minute.

"The gas in burning gives out a great quantity of heat, nearly 3½ times as much as proceeds from the burning of *the same weight of* coal in an ordinary fire; or, in other words, the 4½ feet burner will give out as much heat as a half pound of coal per hour on a grate.

"The theoretic quantity of heat proceeding from the burning of a pound of ordinary coal gas is 34,000 heat units (equivalent to one pound of water heated one degree Fah.), of which one half is radiant heat, and the other is taken up by, and exists in, the gases of combustion.]

"§ II. Having followed the chemical and physical phenomena of the production of illuminating coal gas from bituminous coal, the apparatus and manipulation can next be exhibited; and the works of

the Philadelphia Gas Trust, at Market Street station, can well be taken as a type of practice.

"I have visited these works, in company with others, for the purpose of observation and examination, and can describe with accuracy their construction and processes of working.

"The Market Street station of the Philadelphia gas works is situated on the river Schuylkill, the works themselves being west of Twenty-fourth Street, and between Chestnut and Market, and Market and Filbert Streets, where are located coal houses, retort houses, washer and condenser houses, purifying houses, lime kilns, and other similar buildings; and the station also includes a square, between Market and Filbert and Twenty-third and Twenty-fourth Streets, which square is occupied by holders, meter houses, offices, &c.

"The commencement of the operation is in the retort house.

"[§ § *One.*] The retorts are receptacles for the coal, in which it is enclosed to be heated. In the Philadelphia gas works retort house, they are long vessels of clay, measuring nine feet internally in length, and having a ⌓ section of twenty inches in width and twelve inches in height. The clay is two and a half or three inches thick, and increases in thickness to four inches, in a band around the mouth end, the back end being closed. This *kind* of retort is generally used in America; the section of twelve inches by twenty inches is very common, but thirteen inches by twenty-two inches, and even fifteen inches by twenty-four inches is sometimes used. The length is also, generally, almost universally, nine feet.

"In England, retorts are almost always circular in section, and eighteen inches to twenty inches diameter; and generally, but not universally, eighteen feet in length, and open at both ends. Some differences of climate—the extreme heat of our summers, and the extreme cold of our winters—make the closed retort preferable in this country, and the ⌓ retort is supposed to produce the larger quantity of gas from the coal by more perfect '*carbonization.*' Iron retorts of the same internal dimensions as the clay ones were formerly used. Although clay retorts were introduced before 1820 in Great Britain, yet their general adoption did not occur until about 1850, and their general use here was quite ten years later.

"The Philadelphia gas works continued the use of iron retorts longer than any other works in the world. Clay retorts require the use of '*exhausters*' (or pumps, which in this country are generally

rotary) to remove the gas as fast as formed, to produce a satisfactory yield or quantity of gas from the coal. Iron retorts are yet used for very small gas works, where not over four or five retorts are required to supply the quantity of gas needed.

"Retorts have a '*mouth-piece*' of iron, of the same shape as the retorts, attached by bolts to the mouth end. This mouth piece is about one foot long, and has both ends open, one to attach to the retort, and the other to be covered by a lid, which lid is held against it by a central screw; there being '*lugs*' (ears) on the sides of the mouth-piece, which carry a '*cotter-bar*' (cross-bar of iron) for the screw to go through. On the top or side of the mouth-piece is a '*bell*' (socket) for the stand-pipe.

"The retorts are placed horizontally in '*benches*' (nests) of five (six is as usual in large gas works; while one, two, or three are placed in smaller ones), and are built into an arch-way of fire-brick, nine and a half feet deep by about six and a half feet wide, and six or seven feet high, under the centre of the arch. The arrangement of retorts in the benches is two at the bottom, with a narrow fire-place three and a half or four feet long between them; two above, a little close together; and one in the middle on top. They are supported by the wall in front, and by 'blocks' of fire-brick in the middle and at the back end; so the heat from the fire will rise over them, to the top of the arch, and the gases of combustion will finally escape at the flue holes, which open into the chimneys in the back wall, the holes being below the bottom of the lowest retorts. The chimneys are ten or twelve feet high only. The iron mouth-pieces project and stand in front of the wall.

"The benches are placed in '*settings*,' or a number of benches or arches are contiguous; and the settings at the Philadelphia gas works, and in all large works, are placed back to back, making '*double settings*.' In the retort houses of the Philadelphia works at Market Street, there are six double settings of fifteen benches of fives (12″ by 20″ by 9′), or nine hundred retorts in all.

"The bench is heated to a clear white heat, and never allowed to cool while in service for the production of gas. The coal is brought in wagons of such size as will carry a '*charge*' for the five retorts, in readiness for charging them; and the process of continuous working is as follows:—The workmen first '*draw*' (discharge) the coke; commencing by loosening the cotter-bar screw, which breaks the

joint of the lid with the mouth-piece ; they next light the gas, which begins to escape at the crack, and burn off all that will come out ; then, removing the lids, the flame enters the retorts and frees them from gas on the inside ; a hook of iron is now introduced, and the red-hot coke, just below incandescence, is drawn out upon the floor in front of the retort ; where it is quenched with water, so that it will not continue to burn in a pile, and then shoveled up into a '*coke-barrow*,' and removed to the coke-heap. This operation is substantially the same in all gas works. Generally, perhaps, the hot coke is drawn into a wagon and removed to be cooled outside of the retort house, a procedure which greatly increases the orderliness of the house ; and sometimes the whole retort house has a cellar beneath it, into which the coke is dropped to be quenched.

"I do not know of any other large gas works, except those of Philadelphia, where the coke is quenched in front of the retorts. At these works, the yard is open to the Schuylkill, and the coke heap exposed to public view from Market Street bridge, and it is probable that the quenching at the heap would be too demonstrative of steam and black dust to make it advisable to quench outside. As it is, the ventilators, along the roofs of the retort houses, are but very little above the level of Market Street, and very much below the level of the buildings adjacent to the gas works (within three hundred feet distance), many of which are dwellings ; and consequently the steam from quenching, laden with coke dust, and charged with burned and unburned gases, escapes at the ventilators, and is swept, by any northerly wind, across Market Street ; at times, nearly obscuring the way. The greater part of this nuisance would be avoided by the construction of a suitable coke house, with quenching apparatus, and a tower sufficiently high to condense the vapor and to carry off the gases above the buildings, where they could safely diffuse.

"In New York, at the several gas works which I examined last week in this regard, the quenching of coke is little better provided for ; but as the works are all on a level with the streets and adjacent property, and as any one of the streets themselves is by no means the principal thoroughfare of the city, the nuisance is tolerable. At the Manhattan Works, in New York City (10th Avenue and West Eighteenth Street), the quenching is done out of doors, in an open yard, beside a wall that is twelve or fourteen feet high, on the line of West Seventeenth Street, which street is eighty feet wide and close to the North river, where the largest part of the travel is coal and dirt

carts. At the New York Gas Works (Avenue A and East Seventeenth Street), the quenching is done in the middle of the works, the coke being removed to a floor away from the retorts.

"The retorts having been emptied of the coke from the former charge, they are now filled by shovels with coal from the wagon. In most works they are filled by 'scoops,' or long, half-pipe vessels, which will contain either half charge (when two scoopfuls are used); or, with large scoops, holding the entire charge. The saving of time, the preservation of heat in the retorts consequently, and the proper distribution of coal in the retorts, is the result of scoop-feeding as compared with shoveling. Recently attempts have been made to substitute mechanical feeding and drawing for hand-work, but after eight years' trial in Great Britain, only a degree of success has been attained.

"The task will undoubtedly be accomplished at some not very far-off day; and at the New York Gas Works they have a retort house, nearly completed, with a locomotive mechanical '*charger.*'

"The charge for a twelve by twenty inch retort is, for four-hour charges, two hundred pounds of coal; for four hours and forty-eight minutes (or five charges in twenty-four hours), two hundred and forty pounds; but these quantities are exceeded by some, if not most, gas-works managers—not, however, beyond ten or fifteen per cent. The *charges* of retorts are called four-hour or five-hour (four hours forty eight minutes), to designate that so much time is allowed to work a *charge* of coal and replace the coke by another; that is, in the one case six repetitions of the operation are made, and in the other five, in the course of twenty-four hours. At the Philadelphia Works, an entire bench of five retorts is open at once, and this practice is usual in gas-works in the United States; but in England only a single retort (a through-retort) in any bench, is drawn at once. As there are fifteen benches on each side of each setting at the Philadelphia Works, the same workmen will draw from bench to bench, one after another, so that the operation of drawing retorts becomes pratically continuous for, perhaps, half of every hour of the time during the day and night; the intervals being only those demanded by the endurance of the workmen at such hot and severe labor.

"Having removed the coke and inserted the charge, the lids are closed, the joint being made by a 'luting' of clay and spent-lime, spread upon the edge of a cold lid, ready to replace the hot one, and

the cotter-bar screw completes the operation of the '*stoker.*' Lids without clay joints, in various forms, have recently come into use, with much saving of time and leakage; and one of these is being introduced at the Philadelphia Works.

"The enclosed coal rapidly acquires the heat of the retort; at first the products of distillation, are the vapor of water (steam) and oily hydro-carbons not very completely decomposed; afterwards the gaseous substances separate; and, after three and a half, to four and a half hours, little, except pure hydrogen, passes over. These volatile products pass out through the "stand-pipes," which are six or seven inches in diameter and eight to twelve feet high, being socketed to the mouth-pieces. At the top of the stand-pipes are '*bridge-pipes*,' which are U shape, one leg joined to the stand-pipe and the other joined to, and entering into the 'hydraulic main.'

(To be continued.)

SPEED OF SCREW STEAMSHIPS AND THE SCREW AS A PROPELLING INSTRUMENT.

By John Lowe, of the U. S. Naval Engineers.

In all modes heretofore adopted for measuring the relations between the speed and power of screw steamships, the hull itself has been made the basis of the calculations, or in other words, the power required to propel a given hull at a given rate, has been sought for. Owing to the complex and often arbitrary shape of vessels, a satisfactory method of measurement is difficult of attainment, although numerous rules have been given for this purpose, none so good, however, as to exclude all others by its superior merits. Indeed, a "coefficient," which they all contain, is expressive of the difficulties experienced, and a confession of the defects involved. The more prominent of these rules are:

First, $W = \frac{S^3 B}{C}$ Boulton & Watt's.

Second, $W = \frac{D^{\frac{2}{3}} S^3}{C}$ Atherton.

Third, $W = G\,L\,\frac{(1 + 4\,sin^2 \grave{a} + sin^4 \grave{a})\,S^3}{20000}$ Rankine.

Fourth, $W = D^{\frac{2}{3}}\,(\cdot 1552\,S + \cdot 004684\,S^3)$ Greene.

In which $W =$ indicated horse power,

$S =$ speed in knots per hour,

$B =$ immersed midship section of the vessel,

$C =$ a coefficient,

$D =$ displacement in tons of 2240 pounds,

$L =$ length between perpendiculars,

$G =$ mean girth of the immersed body,

$\grave{a} =$ angles at the points of inflection occurring in the immersed body.

In the first rule this coefficient varies from 800 to 150, in the second from 300 to 50. We must therefore choose from our precedents a coefficient suitable to our proposed vessel. In other words, we must guess at it, which is a truly remarkable way of arriving at a mathematical conclusion. The third rule supposes trochoidal lines, while the fourth, from its simplicity, and that its coefficients are constants, would seem to be the best one. Notwithstanding these and other rules it is a fact that numerous failures have taken place, due to some cause, of which the rules take no cognizance. The trouble is that these coefficients do not discriminate; but embrace the good and bad qualities of hull, machinery and propeller, in one inextricable and misleading confusion. Indeed, in many instances now afloat, vessels built from the same model, and with the same machinery, give very different results in the matter of speed. The inference is then unquestionably correct, that these differences are due to differences in the propelling instrument, and to no other cause, since none other exists. What is therefore required, is a rule discriminating more thoroughly, and which will enable us to improve in our practice. This it is proposed to do in this paper.

Instead of the hull, the favorite propelling instrument, viz., the screw, will be used as a basis for calculation, and no arbitrary coefficient will be introduced, but every step will be taken logically and every quantity distinct, enabling us to discriminate and to fix responsibility of failure where it belongs. It will presently appear that the diameter of the screw should be as large as practicable to obtain the best results. We then assume the other dimensions of the screw and

it remains to measure the power required to revolve it at a given rate. If the immersion of the screw is sufficient, the rules proposed give absolutely correct results, but if the immersion is insufficient, part air and part water will be displaced, and the power will vary, not with the cube of the revolutions, but in a lower ratio. In any case, however, the rule gives enough power, and unless these exceptions are greatly aggravated a very correct result is obtained. Now, although the theory herein involved is simplicity itself and easily understood, yet with singular perversity it is often as easily misunderstood. At the risk of prolixity every step from the elementary will therefore be considered. Attacking each difficulty singly, let us suppose our vessel fast to the wharf, the screw revolving, displacing the water. Underlying all work of this is the formula for accellerated motion, viz.: $v^2 = 2\,g\,h$. In which v = the space in feet through which an abstract body moves in one second of time. In other words, the velocity in feet per second $h =$ the total space through which a body moves, the time being undetermined. $2\,g = 64{\cdot}4$ feet, the increment of gravity.

Now if a unit (one cubic foot) weighing γ pounds, falls h feet, it will perform and accumulate work to itself equal to $\gamma\,h$ foot pounds. If we would instantly stop this body, we must oppose a pressure equal to $\gamma\,h$ or more conveniently $\frac{v^2\gamma}{2\,g}$.

We therefore see how pressure is a function of the square of the velocity. If now this pressure, $\frac{v^2\gamma}{2g}$, thus supposed to be generated, is moved through a space h, it will perform work equal to $\frac{v^2\gamma\,h}{2\,g}$, which is true for all possible values of h. Now then, let h be such a space as can be accomplished in one second; the amount will then be $\frac{v^2\gamma\,v}{2\,g} = \frac{v^3\gamma}{2\,g}$, which is the work done in one second of time. This is an essential point to be clearly understood before proceeding.

Fig. 1

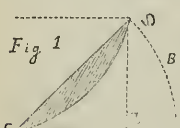


Figure 1 represents a plane, moving against salt water, in the direction b to c, at an angle $acb = \beta$, at the velocity v, in the direction b to c. The work done by this motion is as explained, equal to $\frac{v^3\gamma}{2\,g}$ into the dimensions of the plane, together with a coefficient due to the angle β.

That is, $dU = \dfrac{A\, v^3 \gamma\, \delta\, dx}{2\, g.}$. (1)

In which $dx =$ thickness or depth of the plane in feet,

$\gamma = 64{\cdot}125$, the weight of one cubic foot of salt water,

$\delta =$ the width $a\, b$ of the plane.

A, however, is the coefficient referred to as depending upon the angle B. Its value can be developed logically and is so developed in Weisbach's last edition. The length of the argument prevents its discussion here, however. Experimentally it was found by the writer by taking examples of propellers moving, the vessel being fast to the dock. The work of planes calculated by assuming each circular function was plotted at right angles to radius and integration performed by the planimeter.

The result thus obtained was then compared with the actual, and by this means the conclusion arrived at: That the sine is the proper measure of A. We have then,

$$d\, U = \frac{\sin \beta\, v^3\, \delta\, dx\, \gamma}{2\, g}. \tag{2}$$

To make this equation of further use we must modify it so as to be applicable to the plane as situated in a screw.

For this purpose let $n =$ number of blades in the screw.

$x =$ position of the plane in radius or its distance from the axis in feet.

$\delta =$ length of the blade fore and aft the ship.

$R =$ revolutions of the screw in one minute.

Then $\dfrac{R}{60} =$ Revolutions per second.

and $v = \dfrac{R\, 2\, \pi\, x}{60}$.

$$\text{Therefore } dU = \frac{\sin \beta\, R^3\, x^3\, dx\, 8\, \pi^3\, \delta\, \gamma\, n}{60^3.2\, g}. \tag{3}$$

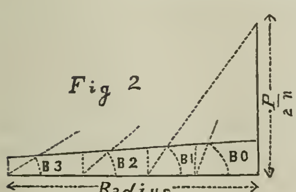


Fig 2

But by reference to Fig. (2). Sin β varies with $2\, \pi\, x$ and with the pitch P of the screw, or with x and $\dfrac{P}{2\, \pi}$.

Therefore, by the figure, $\sin \beta = \dfrac{P}{2\, \pi \sqrt{x^2 + a^2}}$; a being $\dfrac{P}{2\, \pi}$. Substituting

this value of the sine we obtain:

$$d\,U = \left(\frac{x^3\,dx}{\sqrt{x^2 + a^2}}\right) \frac{P\,R^3\,2\,\pi^2\,\delta\,\gamma\,n}{g.60^3}, \qquad (4)$$

which is the complete formula for one plane in each blade situated x feet from the axis. The total work done by the screw is the work done by each and every plane of which the screw consists. This summation is most easily done by integration of this formula. This operation is more simply performed by putting, $z^2 = (x^2 + a^2)$.

Then, $x^2 = (z^2 - a^2)$, $\frac{1}{z} = \frac{1}{\sqrt{x^2 + a^2}}$ and $z\,dz = x\,dx$.

$$\text{Therefore} \int \frac{x^3\,dx}{\sqrt{x^2 + a^2}} = \int (z^2 - a^2)\,\frac{1\,z\,dz}{z}.$$

$$= \int (z^2 - a^2)\,dz.$$

$$= \left(\frac{z^3}{3} + a^2\,z\right) + C.$$

$$\text{Restoring the value of } z;\ \int \frac{x^3\,dx}{\sqrt{x^2 + a^2}} = \left[\left(\frac{x^2 + a^2}{3}\right) + a^2\right] \sqrt{x^2 + a^2} + C.$$

$$= \left(\frac{x^2 + 2\,a^2}{3}\right) (\sqrt{x^2 + a^2} + C.$$

$$\text{or, } U = \left[\left(\frac{x^2 + 2\,a^2}{3}\right)\left(\sqrt{x^2 + a^2}\right) + \frac{2\,a^3}{3}\right] \frac{P\,2\pi^2\,\delta\,\gamma\,n\,R^3}{9 \times 60^3}. \qquad (5)$$

In this expression V is the work done in foot pounds in one second of time which it will be remembered is not the fashionable mode of measurement. Sixty times U will be the work done in one minute, and this divided by 3300 pounds will give what is called horse power.

We have then as a final formula for the horse power required to turn the screw at the dock at the rate of R revolutions per minute,

$$W = [(x^2 - 2\,a^2)\,(\sqrt{x^2 + a^2}) + 2\,a^3]\,\frac{P\,2\,\pi^2\,\delta\,\gamma\,n\,R^3}{3\,g \times 60^2 \times 33000}. \qquad (6)$$

This is not a simple but is a correct formula in the light of numerous examples, ranging from the Tennessee to the Isherwood launch experiments.

Another formula, simpler in form but not otherwise so satisfactory, is to be obtained by regarding $\frac{PR}{60}$ as the velocity of the water displaced by the screw; by this is obtained

$$W = \frac{P^3 R^3 A \gamma n}{2 g \times 60^2 \times 33000}. \qquad (7)$$

A being area of one blade of the screw athwartships. We have thus far considered the screw revolving at the dock; it remains to consider the effect of releasing the vessel.

There are two propositions involved, the truth of which we will prove experimentally.

First, when the vessel was at the dock, the water was displaced by the screw and not the vessel; but when the vessel was released the vessel was displaced and not the water. In the latter case, however, by its mobility the water yielded or "slipped," having the effect of making our common screw a Hunter or differential screw, there being a less displacement per revolution, or a greater number of revolutions to the same displacement and power.

The second proposition is: the resistance which causes slip is of two kinds, first, the resistance caused by the water to the vessel's progress. Second, the resistance of the wind, towing, etc., which may be either plus or minus. In order to compare the performances at the dock and under weigh it is necessary to reduce the revolutions to a standard rate, most conveniently one per minute.

Let $u = \frac{W}{R^3}$ = power at dock at the rate of one revolution per minute.

$u' = \frac{W}{R'^3}$ = power under weigh at the same rate.

Unity = water displaced by the screw at the dock in one minute.

$\triangle$ = relative displacement of the vessel under weigh in one minute.

c = displacement of water caused by external resistances, such as wind.

Then by the propositions $\frac{u'}{u} = \frac{(\triangle \pm c)^3}{1}$. That is to say the work at the dock and under weigh are in the same ratio with the displacements.

Inserting these in (6) and (7), we obtain equations embracing all possible conditions.

Viz.: $W = [(x^2 - 2a^2)(\sqrt{x^2 + a^2}) + 2a^3] \frac{P R^3 \delta\, 2 \pi^2 \gamma n (\triangle \pm c)^3}{3 g. 60^2. 33000}$, (8)

and $W = \frac{R^3 P^3 (\triangle \pm c)^3 A \gamma n}{2 g \times 60^2 \times 33000}$. (9)

For example : When the vessel is fast to the wharf,

Then $\frac{u'}{u} = 1 = (o + c)^3 = c^3 = 1.$

Knowing u; by an indicator card we obtain u', when in smooth water. Then $\frac{u'}{u} = (\triangle \pm 0)^3$ to find $\triangle$.

Knowing both u and $\triangle$; by another card taken under any circumstances we have $\frac{u''}{u} = (\triangle \pm c)^3$ to find c. In other words by an indicator card it is possible to tell the speed of the vessel in the engine room without any other measurement. This the writer has repeatedly done on board of various vessels.

The best proof of this is experiment. Of numerous examples, one will be sufficient to quote, viz.: the performance of the Chippewa at the dock and under weigh as recorded by Isherwood.

Power at the dock, . . .	140·04	Log.	2·1462521
Revolutions at this power, . .	52	52^3	5·1480099
u or power at one revolution at the dock, . .			$\bar{4}$·9982422
Power under weigh uninfluenced by wind, .	239·528	=	2·3793599
Revolutions 75, ...	75^3	=	$\bar{5}$·6251839
w or power at one revolution when under weigh, .			$\bar{4}$·7541760
			$\bar{4}$·9982422
			3)$\bar{1}$·7559338

Relative displacement under weigh, or $\triangle$ = ·82917 = $\bar{1}$·9186446 ∴ (1 — $\triangle$) 100 = 17·083 is the slip. Isherwood records the slip as 16·3 per cent. of the final pitch, which record is sufficiently near to the estimated result to avoid unfavorable comment. The variation in the rate of revolutions is found similarly.

$$\begin{array}{rcr} & & \bar{4}\cdot9982422 \\ & & \bar{4}\cdot7541760 \\ & & 3)0\cdot2440662 \\ 1\cdot206 & = & 0\ 0813554 \end{array}$$

That is the revolutions at the dock being unity, then under weigh they will be 1·206.

As a corollary : Since the power and displacement at the dock is in exact ratio to the power and displacement under weigh, it follows

that there is no loss of effect from slip. The writer has been mislead for years by this term, for its truth was accepted by him. Indeed it will shortly appear that there can be too little slip for economy.

The friction of the screw, like the friction of any other machine, is a factor of the pressure upon the surface and its amount is expressed by the modulus of friction multiplied by the work done by the machine, and we might write it $F = kW$. It is so small an amount that it is herein neglected.

In any screw the best possible diameter is the largest practicable. In Fig. 2 the curve is the boundary of the sin β at every position in radius, since the power to produce a given effect varies with sin β. Fig. 2 proves this proposition, because the sines are smallest at the periphery. For the same reason the area of the screw is to be placed as near the periphery as possible.

The thrust T of the screw is the force exerted by the screw upon the vessel in the effort to propel, and is measured by the equation $T = \frac{P \times 33000}{R P}$ and its equivalents. It is the sum of all the resistances experienced by the ship in her progress.

Slip is caused by these same resistances, therefore slip varies with the thrust. Since thrust is composed of the unit pressure into the area of the screw, slip varies with the unit pressure and inversely with the areas of the screw.

The best possible screw that can be placed in a vessel depends upon the area, and consequently upon the slip of the screw, as controlling elements. Because if the area is too great, too much water will be displaced without corresponding benefit to the effect. On the other hand if the area is too small the slip becomes too great.

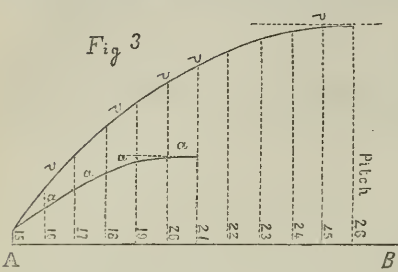
The best possible screw for a vessel is peculiar to that vessel: and that screw will not (except accidentally) be the best screw for any other vessel.

In the present state of our knowledge in order to obtain the best possible screw it is necessary to try one screw in that vessel so as to find by trial the slip of that screw.

From this data the slip of any other screw for that vessel can be found. By the trial the slip $(1 - \triangle)$ is known with its slip. Then $(1 - \triangle') = (1 - \triangle)\frac{A}{A'}$.

In order to find different and corresponding values for $R P$ and A, we use the equations for the power at the dock; after finding $(1 - \triangle)$,

we can then plot $R\,P\,\triangle$ in a diagram to find the maximum value thereof. Fig. 3 is an example of such a diagram.



In this figure the revolutions are limited for the benefit of the air pumps, and variations in $R\,P$ are obtained by varying the pitch P. The values of $R\,P\,\triangle$ are laid off at right angles to $A\,B$ upon equidistant ordinates, each ordinate being numbered by the pitch used.

From the total value of $R\,P\,\triangle$ is subtracted 10 knots, so as to reduce the dimensions of the diagram. The curve *a*, *a*, etc., is the curve limiting the values of $R\,P\,\triangle$, upon the supposition that the views of this paper are correct; that is, that the slip varies with the area of the screw. At the pitch of 20 feet the results are best, which is entirely probable. The curve *b*, *b*, *b*, etc., supposes the slip to vary with the square root of the area, giving a maximum result at a pitch of 26 feet. This result is not so probable, being rather contrary to experience. It is certain however that in the case referred to a better result can be obtained than that at 15 feet, which is the trial position.

The idea of expanding pitches has not been dwelt upon. By Isherwood's experiments it was shown that when the water was deep the displacement of water by the screw was not aft, sidewise, centrifugally, or in any other direction than upward; that is, in the direction of least resistance. The idea of expanding pitches is therefore based upon a misapprehension of the circumstances.

Since when the vessel is under weigh no motion other than the slip is given to the water; it follows that there is no centrifugal action of the screw. The same thing follows from the fact that the water is displaced vertically. Any form intended to prevent centrifugal action, is therefore not only not beneficial, but, on the contrary, is prejudicial, because of increase of actual surface without an increase in the projected surface, beside interfering with the free delivery of the water in its path upward.

A true screw is therefore the best possible theoretically, and it has proved to be as good as any other experimentally.

After an immersion sufficient to prevent frothing is obtained, a greater immersion has no other effect than to increase friction; in proof of which see experiments recorded in *Naval Science*, for 1874.

Chemistry, Physics, Technology, etc.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS DURING THE LAST TEN YEARS.*

By Dr. A. W. Hofmann.

From the *Chemical News.*

[Continued from Vol. ci, page 421.]

Air-pump Sulphuric Acid Machine, by Edm. Carré, of Moislains. —We have still to mention a peculiar ice machine invented by the brother of the above-mentioned F. Carré, and also belonging to the class of absorption machines. Hitherto the idea has only been carried into practical execution on the small scale for domestic use. It was shown for the first time at Paris, in 1867, and has since been exhibited at Vienna. In principle it depends upon the cooling and freezing of water by its own evaporation in a vacuum—the well-known experiment of Leslie. E. Carré arranges his apparatus as follows:—A cylindrical vessel consisting of lead alloyed with 5 per cent. of antimony is half filled with concentrated sulphuric acid which can be kept in motion by means of a stirrer acting from without. With the upper empty part of the vessel is connected on the one hand an air-pump, and on the other an ascending tube fitted with a cock and slightly bent, so that a flask filled with water may be placed in its end, and an elastic band serving for a lute. All the joints are very carefully adapted so as to prevent all access of air. When the air pump is set in action the entire air is removed from the connected apparatus, the water evaporates and is absorbed by the sulphuric acid. After some time a crust of ice is formed in the flask, which increases more and more till the whole, which fills about half the flask, is frozen. The author succeeded in forming 340 grms. of ice

* "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

in forty-five minutes, 60 grms. of water having evaporated. The duration of the operation increases when the sulphuric acid grows hot and becomes diluted. By the use of 1½ litres of concentrated sulphuric acid, 10 flasks of ice, each amounting to 340 grms., can be obtained. The last flask required two hours in freezing, and 75 grms. of water were absorbed. The sulphuric acid had then taken up one-third of its weight of water, and its sp. gr. was 1·6. The cost of a flask of ice was 10 pfennige (about one penny, English) if the sulphuric acid is not put to any further use. In this form the apparatus is exclusively destined for the *Carafe frappée*, *i.e.*, to cool drinking water by means of ice. The writer does not think the machine fit for domestic use, since the smallest entrance of air renders it useless, and satisfactory connection materials are not easily met with. Concentrated sulphuric acid also is an objectionable article in the household.*

uch machines have been recently made by Eigel and Lesemeister, of Cologne. The duty of a machine of the kind described must, on the supposition that the sulphuric acid expended is recovered by means of concentration, be estimated at a very high rate. From a calculation which certainly was only approximate, it would appear that 17 kilos. of ice are produced per 1 kilo. coal used in concentrating the acid. If, in the continuous action of the apparatus, the concentrated acid running off could completely exchange its heat with the dilute acid to be introduced, the effect would be greater by one-third. This result considerably exceeds that of the ammonia machine. The manufacture of ice on this principle would offer certain advantages if the apparatus were differently arranged, since in its present form it is not suitable for lump ice. Perhaps instead of pure water a saline solution might be evaporated, which would be cooled down far below zero, and into which, as in other machines, vessels containing water might be plunged, and the latter might thus be indirectly frozen. The air-pump would require to be put into action only once in order to exhaust the air of the internal space. To open it would be needless, since the sulphuric acid can be introduced, and removed by means of pumps.

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* *Bad. Gewerbz.*, 1868, 153. *Comptes Rendus*, lxiv, 897. *Dingler Polyt. Journ.*, 77 and 417.

III. *Production of Cold by Expansion.*

If a gas is compressed the mechanical power applied is converted into heat and the temperature rises. If equal volumes of different gases at a similar initial pressure are compressed to the same extent, a gas of lower specific heat increases in temperature more than one of higher specific heat, and that in a potentiated manner since its particles, in the first place, assume a higher temperature by an equal increment of heat, and secondly, since the hotter gas possesses a greater tension and opposes more resistance to compression, whence more heat is evolved. Different gases of equal initial temperature and tension, when compressed to an equal volume, not only attain unequal temperatures, but unequal pressure. The following table shows in what proportion atmospheric air of mean tension increases in temperature if compressed at an initial temperature of 20° C.

Pressure in atmospheres - - -	1	2	3	4.
Temperature - - - - -	20	85	130	163.

If a hot compressed gas is allowed to re-expand, always under full pressure, the heat is transformed into mechanical power, and a fall of temperature ensues in the same measure as the rise during its compression. If a hot and compressed gas is cooled down and then expanded, it falls below the initial temperature, and very great degrees of cold can be attained. Thus air at 2, 3, 4 atmospheres, cooled down to 30° C., and allowed to expand to 1 atmosphere yields respectively the temperatures of 25°,—53°,—70° C. It is pre-supposed that the air, like steam in an engine, works outwardly; if it rushes into an empty space the temperature of the whole mass experiences no change, since the heat lost by the initial expansion is reproduced by the impact of the molecules against the sides of the vessel. If the air drives before it a pressure smaller than corresponds to its own tension, *e.g.*, if, having been strongly condensed in a receiver, it escapes into the open air its fall in temperature is less than as stated above. On these principles depends the application of air to the production of cold and the preparation of ice.

Accurately regarding the various stages traversed by the air, the arrangement of an air ice machine would be, in principle, as follows: —The air is condensed in an especial cylinder up to a certain pressure, at which it is then forced into the cooling apparatus. Whilst it

here parts with its excess of heat, its volume, at the same pressure, becomes reduced in the proportion—

$$\frac{273+t}{273+\mathrm{T}.}$$

Hence it passes into a second cylinder where expansion takes place; the processes taking place here in the reversed order from what ensues in the compression cylinder, and the effect agrees exactly with that of an expansion steam-engine. The air here becomes very cold and is forced by the return of the piston into the freezing chamber where the ice boxes stand. After passing through this apparatus it arrives anew in the compression-cylinder to repeat the same circuit. The expansion-cylinder here corresponds to the evaporation-receiver in other machines. The distinction, however, must be noted that but a small quantity of air is kept in circulation, whilst in other systems a large stock of the matter inducing the cold is present in the state of a liquid. It will be seen that the course of the conversions is exactly the same as in a "caloric engine," but in a reversed direction, and the performance of the one and the other may be calculated by the aid of the same formulæ. The writer has carried out such a calculation,* from which, it appears, that when the air, at an initial temperature of 20° C., is compressed to 3 atmospheres and then cooled down to 30°; the theoretical yield is 5 kilos. of ice per 1 kilo. coal consumed, whilst at 2 atmospheres the yield is 6 kilos. The production is in general terms inversely as the condensation of the air or the difference of temperature thereby produced. But, on the other hand, the dimensions of the cylinders for a given yield must be so much the larger the smaller the condensation which is to be applied, as appears at once on a close examination of the procedure. The actual performance of the machine may perhaps be considered equal to one-half of the theoretical yield. Hence it appears that the air machine is far inferior in its performance to the ammonia machine.† The reasons are the same which have been already advanced in the comparison of the ammonia and the ether machine. The efficacy of the machine may, however, be considerably increased, if, as we shall further explain below, the air is at once cooled during compression,

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* *Bad. Gewerbz.*, 1869, Appendix Number.

† In consequence of the low specific heat of the air, relatively large quantities must be employed, whence the cylinders and the resistance of friction to be overcome are very large.

so that it cannot become heated, in which case the cost of compression is much reduced. An advantage of the air machine as compared with other systems is that no offensive or combustible substances are brought into play, and that there can occur no waste of a costly material.

An air machine is mentioned for the first time in 1863.* It was patented in England in April, 1862, by A. C. Kirk, of Bathgate. It consists of upright cylinders, the lower part of each being connected with the upper part of the other by a channel, fitted with a valve opening upwards. The pistons have valves opening downwards. The lower covers of the cylinders are kept cold by a stream of water, whilst the upper give off cold to salt water. According to the somewhat obscure description the action is as follows:—The piston of the cylinder *a* on descending compresses the air below it, and expands that above it, the compressed air being forced into the upper part of the cylinder *b*. On the ascent of the piston *a* the expanded air passes through the valve of the piston from the upper into the lower part of the cylinder, whilst the piston receives above at first compressed air from the lower part of the cylinder *b*, which, when the latter is emptied, begins to expand and to be cooled. The same processes take place in the cylinder *b*. Consequently one and the same quantity of air is always employed, which circulates from one cylinder to the other. It is asserted that 1 horse-power yields, in twenty-four hours, 106 kilos. of ice, the yield of the ether machine being 110·5 kilos.,= 2 kilos. ice per kilo. of coal. In Young's paraffin works at Bathgate there was at that time a machine which turned out in twenty-four hours 2 tons or 2032 kilos. of ice. The result is somewhat small; the cooling surfaces of the cylinders are certainly not large enough to take up heat and cold quickly and completely. Indeed a series of theoretical objections might be urged against the construction of the

* *Pract. Mech. Journ.*, 1863, 113. *Dingl. Pol. Journ.*, clxx, 241. Wagner, *Jahresbericht*, 1863, 568. However, a patent for an air ice machine was granted, in England to one Nesmond, of Bellac, in France, as early as 1852. It compressed air to 20 atmospheres by means of a hand air-pump in a vessel like a boiler placed in cold water. After cooling the air passed into a second vessel where were the substances to be cooled or the air to be frozen, and escaped thence into the open air. It was asserted that a man could force the air into the compression-vessel in eight minutes, and thus produce 8 to 10 lbs. ice per hour. The action of the apparatus was therefore intermittent and not economical, and indeed the whole arrangement left much to be desired in point of convenience.

machine, which is very simple. In 1864 it was announced that this machine was still at work in Young's establishment, producing a ton of ice with the consumption of a ton of coal, worth (then) four shillings. It was also declared that its efficacy was equal to that of the ether machine.* This would be a far smaller yield.

In 1869 the design and description of an ice machine constructed by F. Windhausen, of Brunswick,† were made public. It has only one cylinder, with a piston of the diameter of the height of the stroke. On one side of the piston there occurs compression and on the other expansion. The compressed air is forced through a cooler with a large surface, which serves at the same time as a reservoir for the compressed air. Whilst on one side of the piston the air is compressed it expands on the other. On the return of the piston the cold air is forced into the ice-chest, from which, when deprived of its cold, it is immediately drawn on the other side of the piston. That side of the long cylinder in which condensation takes place is surrounded with water as a cooling agent, whilst the other end is packed with a bad conductor of heat. The broad piston renders it impossible for an equalization of temperature to take place within the cylinder. For this purpose there requires an especial external arrangement for the admission and for the cutting off of the air which enters the expansion end. If the object is not to make ice but to cool spaces, the expanded cold air is forced directly into these, whilst the fresh external air is drawn into the compression end of the piston. As regards the performance of the machine nothing has transpired.

In the summer of 1871 the author saw at Berlin a powerful ice machine destined for New Orleans, constructed and experimentally set up by Windhausen. The construction was different from that above described, the compression and expansion cylinders being distinct, according to the scheme which we considered as most correct in principle, and took for the foundation of our preliminary investigation. It yielded air at —40° C., which was filled with abundant snow-flakes. As the compression cylinder constantly drew in fresh air, hygroscopic water was deposited in the cooler, where on account of the contracted space it could no longer remain in the state of vapor. From there the air, saturated with water, passed into the expansion-cylinder, and

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* *Mech. Mag.*, 1864, 245. *Dingl. Pol. Journ.*, lxxiv.

† Windhausen, *Mech. Mag.*, 1869, 387. *Dingl. Pol. Journ.*. cxcv, 115. Wagner, *Jahresbericht*, 1870, 542.

in consequence of the cold produced by the expansion the greater part of the existing vapor was necessarily deposited as snow. This circumstance very much interfered with the working of the machine, as the friction of the piston was considerably increased by the snow, which also choked up the escape-pipes. The latent heat set at liberty acted also in opposition to the fall of the temperature even though the sum total of the negative heat units was not lessened. The piston was appropriately lubricated with glycerin. The author could ascertain nothing as to the experimental measurements made to determine the actual effect of this machine.

Since the beginning of 1873 Nehrlich and Co., of Frankfort-on-the-Main, make the Windhausen machine with two cylinders of one size only, with especial regard to the demand in breweries. It requires a 40-horse power engine, and is guaranteed to yield hourly 2500 cubic metres of air at temperatures of from —30° to —50°. If we assume that these temperatures refer to initial temperatures of from 10° to 30° the total reduction of temperature amounts to 60°, whence the amount of the negative heat units may be calculated as 50,000, corresponding at most to 400 kilos. of ice. If the production of ice were the object in view the same quantity of air might be made to circulate. A steam-engine of 40-horse power consumes hourly 80 kilos. of coal; consequently 1 kilo. of coal would give 5 kilos. of ice—a very favorable result. Such a machine, including the engine, cost in 1873 66,000 marks (£3300).

L. Mignot,* of Paris, in 1870, constructed also an air ice machine with distinct compression and expansion cylinders. It is distinguished from that of Windhausen by the arrangement that a small pump injects water into the compression-cylinder, and that the air in the condenser sweeps over open water. This arrangement is, without doubt, advantageous. The labor of compression is much reduced when the temperature of the air is kept low. The water cannot have an injurious effect in the air since the cooled and compressed air is in any case saturated with moisture. It may therefore be expected that the compression of the air will be effected at a less cost, and its complete refrigeration will require a smaller condenser. Particulars concerning this machine have not transpired. The more recent Windhausen machines are also provided with an injection apparatus.

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* L. Mignot, *Mech. Mag.*, Dec., 1870, 404. *Dingl. Pol. Journ.*, cxcix, 362. Wagner, *Jahresbericht*, 1871, 696.

According to experience hitherto, the air machines seem better adapted for the immediate application of cold air than for concentrating and storing up cold in the form of ice, in which respect they fall too far short of the ammonia machines. They may probably be found serviceable in breweries for cooling cellars. Motive power is always to be found in such establishments with which the air-pumps can be readily connected. The introduction of cold air into the cellars secures the further advantage that they are kept very dry by means of this air, which during its compression and expansion has been to a great extent deprived of its moisture, and hence no mould is formed. Cooling with ice, on the other hand, saturates the air of cellars with moisture, and keeps it stagnant. The whole process can be carried on in breweries at a relatively small expense, as in such establishments much heat and especially much hot water is required, and thus both the escaping steam and the hot water obtained by cooling the compressed air can be utilized. An air machine supplied by Merlich and Co. to Hildebrand's brewery at Pfungstadt, near Darmstadt, has given for a year very satisfactory results. The principle of the air machine seems also especially adapted for ventilation where it is desirable to combine reduction of temperature with renewal of the air, as in hospitals, public rooms, and steamships. Here a trifling expansion and a small degree of cold would suffice, and hence the working cost would appear relatively low. We may look forward with interest to the further development of this subject.

We have still to make mention of a more extended theoretical investigation which Linde* has given to the public on the "withdrawal of heat at low temperatures by mechanical agencies." The main result which he has arrived at in the way of calculation—which, however, appears at once on an attentive physical consideration of the changes that take place—is that for the economical working of ice machines the temperature of the body used as a medium during expansion must not be lower, and during compression not higher, than is absolutely necessary. This condition has hitherto been frequently overlooked, and ignored. Whilst it has frequently been said, in explaining the merits of an ice machine, that it works at such or such low temperatures, the very opposite should be the case; it should be shown that the machine produces ice without requiring a temperature far below

* Linde, *Bayer. Industrie u. Gewerbeblatt,* July, Nov., and Dec., 1870.

the freezing-point of water. The above-mentioned praise is merely a certain proof that the machine consumes much power needlessly. Certainly in this case the machine may be smaller and the first outlay easier, but this advantage generally vanishes in comparison with the drawback of increased working charges. Linde proves by calculation that in a theoretically perfect machine, which produces ice at —3° from water at +10° C., 1 kilo. of coal should yield 100 kilos. of ice. He combines also with his theoretical researches a critique on all ice-machines hitherto constructed. All makers of such machines should make themselves thoroughly masters of the principles here developed, which would keep them from going astray.

In 1873* J. Armengaud communicated certain theoretical speculations on air-machines to the French Academy, which, however, contained nothing essentially novel. He lays especial stress upon the importance of cooling the air during compression by means of water. The difficulty of effecting this by means of water injected in the moment of compression he overcame by introducing into the air, as drawn in, water, by means of Gifford's injector, probably as fine spray. According to its experiments it is most advantageous to work with a degree of expansion =2, in which case the power exerted, in proportion to the cold produced, is only half as great when the refrigeration is carried on during compression as if executed previously.

Nature of Artificial Ice.—Ice rapidly produced, at a very low temperature, is quite opaque and of a milky white. From this appearance —so different from the vitreous, transparent aspect of natural ice— the strangest conclusions have been drawn as to its behavior. Sometimes it was assumed to be more and sometimes less permanent, sometimes to have more and sometimes less cooling power than natural ice. The truth is that artificial and natural ice differ merely in appearance. A piece of the former just taken out of the machine is of course colder than a block from the ice cellar, and consequently melts rather more slowly on exposure to the air. Equally large pieces of natural and of artificial ice, at the same temperature, melt with equal speed under similar external conditions, and exert equal refrigeratory powers.

(To be continued.)

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* Armengaud, *Comptes Rendus*, lxxxvi, 626. Dingler, *Polyt. Journ.*, ccviii, 174

Evaporation of Liquids Aided by the Infusion of Air.—By a communication from M. Ed. Moride, of Nantes, France, published in *Les Mondes* (Paris), May 18th, 1876, the following account of experiments in evaporation in the concentrating of brine, at salt works, and of the juice of the beet-root in the process of sugar making, is given.

An apparatus constructed by MM. La Pommeray and Pinel has been placed at the salt-works of Croisic, belonging to MM. Benoît. It has worked with great advantage, producing much economy in time and a saving of nearly 40 per cent.

At the Etienne sugar refinery the method has been applied in the working of beet-root juice to the weak liquor of 5°, as well as to syrup of 25° density, without alteration of the juice or change of color. Both the raw juice and the syrup have been concentrated nearly to 42° density by a temperature of 80° to 86° centi. (176° to 187° Fah.), and have crystallized perfectly without any greater production of glucose than accompanies other methods of working. The evaporation progresses at the rate of an increase of density of 5° per hour, between 6° to 25°, when it is accellerated to the rate of 6°, 7°, 8° and 11° of concentration per hour.

At the A. César refinery the apparatus for infusion of air has been applied to a *vacuum pan*, and works perfectly, only that the vacuum cannot be maintained constantly except at 45° centi. (103° Fah.); otherwise, by admitting less air the vacuum can be raised, but the temperature will then be increased, to the detriment of the formation of a regular grain.

The sum of the results of the experiments in sugar making is—

1. That the "insufflation" (infusion of air) augments considerably the evaporation of a liquid.

2. That this method procures an economy of fuel of nearly 40 per cent., together with much saving of time, so great as to permit an ordinary boiler of evaporation to accomplish *five times* the usual results.

3. That the "insufflation" is without injurious action upon the sugar solutions, that it neither affects the color nor inverts the crystallizable sugar.

It is demonstrated to be possible then, with all security, to apply this novel method of evaporation to sugar-juice nearly to 35° or 40° of density; but the termination of the boiling may be effected in a vacuum pan, as is ordinarily done, or may be effected in free air.

NOTE BY THE EDITOR OF THE JOURNAL.

The method of "insufflation" and evaporation referred to in the preceding article is simply the blowing of streams of air, not necessarily heated, into a liquid warmed by some usual means to some desired temperature, which may or may not be the boiling point of the liquid. The active circulation promoted by the levity of the air-bubbles and the extended surface which is given for the evaporation of vapor to take place from, is supposed to greatly increase the efficiency of the heating surface to dispense heat to the liquid, by increasing the *difference* of temperature of the liquid where it comes in contact with the heated surface. The claim of saving of fuel, that is, of effecting a greater evaporation by the same quantity of heat, would seem to need more positive evidence before obtaining belief than is given by assertion, for the admission involves the establishment of new laws in physics, but the possibility of accelerating the process of evaporation by the method can be readily conceived and admitted in moderate degree; certainly, however, not that the same heating surface could be made practically efficient for "five times the usual results."

The familiar process of cooling a hot drink by blowing upon it, is the readiest example by which "evaporation by insufflation" can be comprehended, and although the process of *drying* or *desiccation* by means of currents of air is very generally practiced, yet the corresponding performance of evaporating a liquid by the same method is thought to be novel. In viscous liquids the application of this method would seem to have an absolute practical value, even if the excessive claim for merit in economy of fuel were found to be unwarranted.

The Production of Potash.—The production of potash commercially, has entirely changed aspect within these last twenty years. Prior to that time wood ashes were exclusively employed in its manufacture, but now more than half is procured directly from mineral sources. This is principally owing to the fact that the immense salt mines of Stassfurt have been found to yield a profitable supply of potash, and the knowledge of this fact has given a new impetus to saline deposits wherever they occur.

GREAT WESTERN RAILWAY.

The following observed speeds of a regular railway train in England is extracted from the correspondence of the *English Mechanic* April 19th 1876.

Miles.	Stations.	Arrival.	Departure.	Speed.
	Bristol		2·26	
$44\frac{3}{4}$	Taunton	3·18	3·20	51·6346
$75\frac{1}{2}$	Exeter	4·0		46·125
				97·7596

$= 48·8798$ average.

Or average for whole distance $= 118\frac{1}{2}$ miles $+ 75\frac{1}{2}$ miles $= 194$ miles (11·45 to 4 o'clock) $= 255$ minutes — stops $(10 + 2 + 5 + 2)$ 19 minutes; $\therefore$ average $= \frac{194 \times 60}{236} = 49·32203$ miles per hour.

Miles.	Stations.	Arrival.	Departure.	Speed.
	Paddington		11·45	
$5\frac{3}{4}$	Ealing		11·54	38·3333*
$7\frac{1}{2}$	Hanwell		11·56	52·5
$9\frac{1}{4}$	Southall		11·58	52·5
11	Hayes		12·0	52·5
$13\frac{1}{4}$	Drayton		$12·2\frac{1}{12}$	64·8
$16\frac{1}{4}$	Langley		$12·5\frac{1}{4}$	56·8421
$18\frac{1}{2}$	Slough		12·8	49·0909
$22\frac{3}{4}$	Maidenhead		12·13	51
31	Twyford		12·21	61·875
36	Reading		12·27	50
$41\frac{1}{2}$	Pangbourne		12.33	55
$44\frac{3}{4}$	Goring		$12·36\frac{1}{4}$	60
$47\frac{3}{4}$	Moulsford		12·39	65·5555†
$53\frac{1}{4}$	Didcot		12·45	55
$56\frac{1}{2}$	Steventon		12·49	48·78
60	Wantage		$12·52\frac{3}{4}$	56
64	Challon		12·57	56·4705
$66\frac{1}{4}$	Uffington		$12·59\frac{1}{2}$	54
$71\frac{1}{2}$	Shrivenham		1·5	57
$77\frac{1}{4}$	Swindon	1·12		49·2857
				1086·5330

$= 54·32665$ average.

miles per hour.

* Minimum. † Maximum.

"THE PHYSICS OF THE ETHER."*

By William B. Taylor, Washington, D. C.

(Continued from Vol. ci, p. 413.

In regard to the still more recondite phenomena of *chemical* elective affinity, Mr. Preston is equally at home, and equally self-complacent.

"The vast variety of wave period observed, points all the more convincingly to the fitness of the molecular vibrations as the regulator of the complex and varied effects exhibited in the movements of molecules in "chemical action," or those diverse molecular movements which belong to the science of chemistry. . . . In viewing the phenomena of the movements and mutual actions of molecules as a physical problem, it really is not conceivable that anything could be more admirably adapted to produce the effects than the vibrations of the molecules, which also, by variation of wave period, are capable of building up the almost endless variety of chemical compounds," (pp. 32, 33).

That is, molecules agitated with a red vibration of the ether, will naturally be made to "approach" other molecules similarly timed; so yellow moving molecules will affect each other, while extra violet molecules will in like manner only accept harmonious partners in the chemic dance. And while this special selection, whether of ethereal or of molecular periodicities, is in action, there is still sufficient of the unselected vibrations to secure gravitative and cohesive "impulsions," for the ethereal reservoir of motion is by assumption infinite and inexhaustible.

As to the actual measure of the tension of chemical affinity, Mr. Preston has calculated that a hydrogen molecule in combining with an oxygen molecule to form water, supposing it to move through one millionth of an inch, exhibits an energy which "is 424 billion times greater than the weight of the double hydrogen molecule, or the value of gravity acting upon it," (p. 67), and that accordingly,

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* Mr. Preston has recently published a *résumé* of his lucubrations in a series of eight articles, under the rather inappropriate title of "The Origin of Motion,"—in the columns of our excellent English contemporary "*Engineering*," for January 7th, January 21st, February 4th, February 25th, March 17th, March 31st, April 28th and May 12th, of the present year.

"If we take a grain of water [one drop], then the value of the strain required to separate the molecules being 424 billion times the weight of the hydrogen molecules, and the total weight of the hydrogen molecules in a grain of water being one-ninth of a grain, we have accordingly 424 billions $\times \frac{1}{9}$ grain, $=$ 3 million tons in round numbers*. . . . As before remarked, a millionth of an inch being unquestionably too large as an estimate for the distance traversed, the result arrived at for the absolute value of the strain will be by so much less than the actual fact," (p. 68).

With this general conception of the chemical phase of ether motion, let us see how Mr. Preston contrives to produce an explosion within a loaded gun, by ethereal vibration.

"Considering the state of the case previous to the discharge, it is well first to have a clear conception of the fact of the ether pervading with the utmost facility the body of the cannon, the ether occupying the molecular interstices and surrounding the molecules of the metal, so that, therefore, the slightest difference of the ether due to any disturbing cause, would immediately readjust itself across the body of the gun. . . . We observe, therefore, before the discharge, the ether enclosing its intense store of motion pervading the body of the cannon, and inserting itself between every molecule of gunpowder, ready to part with a portion of its motion at any instant. . . . We note, therefore, an ingeniously disposed and delicately poised train of matter, at present in a state of dynamic equilibrium, the whole pervaded by a physical agent of exhaustless energy from which it is only necessary to divert a small portion in order to cause the propulsion of the shot. The blow struck upon the percussion cap, by urging a few of the vibrating molecules into proper proximity, is sufficient to upset this equilibrium of motion and bring the ether into action, the motion passing from the ether through the train of matter to the shot, and thence to the ether (in the waves emitted by the incandescent gases, the work of the shot, etc.) in a cyclical process. . . . During the time of the explosion, the ether particles in the bore of the gun lose a certain fraction of their normal velocity by transference to the molecules of gunpowder, which loss of motion, if it

* It may be well to notice here, that the average distance of molecules from centre to centre, in the liquid or solid form of matter, has been successively estimated at values not very far removed from the 200th millionth of an inch, by Waterston, in 1857; by Loschmidt, in 1865; by Stoney, in 1868; by Thomson, in 1870; and by Maxwell, in 1873.

continued without renewal, would conduce to a reduction of the ether pressure in the interior of the gun; so that the inference is necessary that on the instant of the disturbance of the equilibrium of the ether pressure by the motion transferred to the first few molecules of gunpowder, a *readjustment of pressure* commences to take place across the body of the gun in the form of a wave, the free communication existing with the external ether rendering it impossible for any appreciable difference of pressure to accumulate," (p. 101). "The molecules of gunpowder merely serve as the convenient mechanism to transmit the motion of the ether to the shot, for the gunpowder, like the shot, has no motion of its own, and therefore must have the motion imparted to it. The ether, on the other hand, does not require to have motion imparted to it, since it already has motion. The ether is, therefore, the only competent source of motion, or the ether transfers motion which it already has through the gunpowder to the shot; the sum of motion thereby remaining constant," (p. 103).

So to give the required dynamic energy (beyond that of ordinary temperature) to the material particles of the gunpowder, it is necessary that the illimitable store of motion in the ether should suddenly be called upon; and as it could not be supposed to enter at the muzzle of the gun at the moment of discharge, it has to pass without ceremony through the walls of the gun; although Mr. Preston has previously told us that every molecule of iron in the gun is held firmly in its relative position by *statical* vibrations of the intervening ether, inducing a rarefaction whereby the external impacts of the ether exert an excess of coercive dynamic pressure—say of 10 tons to the square inch. But what becomes of this differential coercive bond when the violent influx of ether pressure is passing through transversely to these interstitial stationary vibrations?

Such is the wonderful physical philosophy by which the tenacity of guns is established, and the disruption of their discharge simultaneously effected. Of *static* force Mr. Preston has no conception, for with him motion is everything, and everything is motion. "Potential energy" in such a system is as inadmissible as "action at a distance." How can a body at rest possess any power? (p. 9). Every child knows that a thing cannot act where it is not; although its apple *does* slip from its fingers without strings from below, and without "impulsions" from above. And every child of course knows that when a clock is wound up, *with the pendulum at rest*,

"Unless *motion* be imparted at the time, energy cannot be expended at all; for to expend motion without imparting motion would be to annihilate energy. Indeed, the motion imparted is itself the measure of that expended, and is the sole cause of its expenditure; *i. e.*, motion can only be expended in the communication of motion, and in that fact lies apparent the principle of the *Indestructibility of Motion*," (p. 93). "The process of coiling a spring, as by the winding up of a clock for example, in which act the vibrating molecules of the spring are displaced, affords another illustration of work consisting in the communication of motion to the ether," (p. 99).

"Now it follows from the principle of conservation, that the previous existence of motion is the absolutely essential condition in order for motion to be developed, for unless motion previously existed, motion could not be expended in the act of developing motion," (p. 12).

So whether gunpowder be kept in a magazine for an indefinite number of years, or a powerful spring be placed under severe tension with its detent unreleased; whether the Great Eastern is held securely by its anchored cable during a storm, or carbon deoxidized by solar energy many million years ago, is reposing in unworked coal-fields, in each and every case the store of potency is simply, *motion!* When coal is finally mined and placed within the furnace of a steam-engine,

"All the motion developed at combustion, and imparted to the ether in the form of waves of heat, comes from the ether at the time of combustion; so that the process of combustion might be continued indefinitely without the slightest absolute gain of motion; or the interchange of motion constituting combustion is quite independent of the fact whether energy was expended in the previous act of separating the carbon or not," (p. 96).

"The interchange of motion may be said to form the whole basis of the great principle of conservation, for the very idea of the interchange or transference of motion, itself precludes all idea of the possibility of the annihilation of motion; or the only possible method of getting rid of the motion of a mass of matter is by transferring that motion to another mass or masses," (p. 89).

This radical fallacy of the "indestructibility of *motion*" has, unfortunately, gained a considerable acceptance, and has received the support of names much higher than that of Mr. Preston. Even so

clear and generally correct a thinker as Herbert Spencer has permitted himself to write a chapter on "The Continuity of Motion," (*First Principles*, 1st ed., part ii, chap. 6).

The hammer motion expended in making a horse-shoe has but a relatively small portion of it converted into the vibratory motions of sound and heat. The greater portion, and the whole useful portion of the hammer blows, is *consumed* in simply displacing iron molecules in a desired direction; to effect which, a very considerable amount of *static* tension has to be overcome in the resistances to a disturbance of position offered by the particles; and this molecular resistance constituting the hardness of the material, is precisely what gives the finished product its useful function. So when the ram of a pile-driver is laboriously raised to its highest position, and there held by the grapple, what has become of the motion employed in raising it? Has the arrested lifting power been converted into heat vibrations, carefully conserved and patiently waiting to be re-converted into falling motion when the director shall release the detent? Surely such an idea can hardly be entertained for a moment by an intelligent physicist. Supposing that for sufficient reason it is determined not to let the ram fall till the following day, where then is the motion of elevation hiding itself all this time?

Mr. Preston, recognizing no equivalent of force conserved in the "potential" state of matter raised to a mechanical advantage of *position*, at which time all effective motion has ceased and forever disappeared, supposes that

"At the particular instant when the machinery was first started, motion was derived from the ether without being simultaneously transferred to the ether; this relatively small amount of motion (representing the motion of the machine) remaining abstracted from the ether so long as the machines are in motion, but when the machines stop, this motion is returned to the ether in the form of waves of heat," (p. 98).

In this illimitable ocean, therefore, the waves of motion are supposed to remain in action, until, in the case of the pile-driver, at the slipping of a trigger they suddenly reappear in the descending ram.

One is tempted to ask, what is the special necessity or advantage of this circuitous "transfer of motion," this "cyclical process," in every mechanical effect? Why not devise some way of more

directly availing ourselves of the exhaustless store of motive power ever present in the infinite depths of ether, and ever ready to respond with the quickness of light to the tremblings of matter? Why not dispense with the intermediate *ram?* The stock of coal is very finite; the stock of ether energy—infinite. The same thought appears to have occurred to the ingenious author of the "Physics of the Ether."

"If the vibratory motion of molecules could be brought under control, and thus be temporarily got rid of by utilization in any way, then the above result would be attained, or the molecules would separate without the performance of work; as we have before pointed out that there are certain considerations which would indicate that this result is actually attained in nature, in the disintegration of matter at a low temperature," (p. 96).

"Perhaps a partial reduction of the vibrating energy might help, but we are not restricted to discrete molecules, and possibly the reciprocating movements of approach and recession of masses under the action of the ether in the 'electric' and 'magnetic' phenomena, might be found more subservient to this special object, and thus the enormous stores of motion present on all sides be made of more practical avail than by the present methods of utilization. At all events, it appears an anomaly that motion should be only obtainable from a source on the condition of the expenditure of an equivalent amount of machinery," (p. 97).

The anomaly is obvious on the assumption that force and its offspring motion are not derived from the molecules of sensible matter, but have their origin in an entirely *external* source. If the power antecedently derived from the ether by a mechanical or chemical train were at each instant precisely equal to the power expended in useful work, we should have a very satisfactory perpetual motion. Although in terms Mr. Preston accepts the modern doctrine of the "conservation of energy," yet, as this is expressly applied by him to the infinite store normally existing in the *ether*, and as the quantity of energy manifested by matter is declared to be variable (pp. 95, 96, and 98, 99), it is too obvious for remark that the grand theorem becomes practically valueless, and that all the attempts hitherto made to deduce the principle from the deportment of sensible matter are utterly illusory and fallacious.

But what is the *evidence* adduced by the author to give plausibility to his stupendous fabric of conjecture? So far as can be discovered,

the *a priori* argument already quoted: "Since a rarefaction of the medium constitutes the only possible physical means by which an 'attraction' (approach) can be produced by vibration, . . . it therefore follows that a stationary vibration of the medium can be the sole physical cause concerned in producing an attraction," (p. 49). Alas, this "sole physical cause" has not even the indirect support of fitness, or of congruity. The supposition is not in conformity with the most obvious characteristics of molecular physics; its postulates are not even consistent with each other. The conditions required for statical phenomena are incompatible with those required for dynamical phenomena.

When we are told that *In principio erat Motus*, rendering futile any inquiry into the origin of this "phenomenon,"* that this phenomenon, though usually "concealed" in the impalpable ether (as the molecular movement of normal temperature is in the atmosphere), becomes *sensible*, as in some sense a function of material masses—that it is not strictly a function of mass, since its energy is a product of the amplitude of vibration, or, as we might say, of thermal activity; and, accordingly, that with the lowering of this activity, the differential of external "impulsion" is reduced, and the tendency to "approach" thereby diminished, whether between molecules or masses,† we see, at a glance, that such presentations are in no respects accordant with the ascertained system of nature; and that they fail, signally, to give us any approximate representation of the *coercive forces* actually manifested in matter.

The subject of tides has not been specifically discussed; but any scheme of physics requiring the affirmation that the water of the ocean is lifted by ethereal "impulsions" from beneath, which have

* Mr. Preston does indeed make the concession, though with a different intent, that "if all physical effects be effects of 'motion,' then in principle, the one fundamental 'cause' for investigation must be the *cause for motion*, or the cause determining the vast variety of motions constituting physical phenomena. To admit, therefore, a theory which would do away with the necessity for investigating the *cause* of motion, would be to admit a principle which, if carried out universally, would close the field for physical research altogether, or which would assume that physical effects were inexplicable," (p. 5).

† "Since, when a physical cause ceases to exist, the effect also ceases, it follows that at the absolute zero of temperature (absence of vibrating energy) the general phenomenon of 'cohesion' including the aggregation of molecules in 'chemical union,' would cease to exist." (*Ether*, p. 64.)

passed through the solid portions of the globe in the direction of the lunar column of stationary ethereal vibrations, may be at once dismissed, as being too whimsical and chimerical to deserve serious attention.

Mr. Preston has professedly undertaken the difficult, but most important, discussion of the "physics of the ether." But what is the "ether?" or rather, what is the foundation of the conception now received into science under that name? The demonstration that radiant light and heat are but forms of vibratory movement, seems to render necessary the presence of a material medium in celestial spaces, capable of receiving and transmitting such movement. It transcends all our experience, and all conceptions derived therefrom, that motion (defined as changing position) can exist apart from material substance; or, in other words, can be transmitted through a vacuum. Hence, the inferred necessity of a pervading inter-stellar medium, having the rarity and elasticity requisite to perform this office. Without *such* supposed necessity, the notion of this illimitable ocean of "ether" would probably be abandoned at once, by almost every astronomer and physicist; for it is really a greater strain upon the scientific imagination, than even distant attraction itself. Above all things, then—*first* of all things—the "ether" must be *luciferous.*

Now, Mr. Preston, in his enthusiasm of ether, has so overburdened it with duty, that he has quite impaired its primal function of transmitting in *straight lines*, with *uniform velocity*, and in *determinate planes*, a succession of undulations. By his hypothesis, celestial space (at least within the solar system) is traversed by moving lines of *stationary vibrations*, exhibiting a permanent *rarefaction* to render possible the differential of dynamic pressure, which constitutes the foundation of his system. It is hardly necessary to remark, that in a medium so constituted, luminiferous waves could never have either a uniformity of velocity, or a uniformity of direction. Stellar occultations, instead of being mathematically determinable, would be subject to incalculable anomalies: "aberration," instead of being uniform, would be scarcely ever self-comparable; and from the eclipses of Jupiter's satellites, we could never have determined the actual velocity of light.

Our author's hypothesis assumes a normal, aboriginal, intestine motion of the ethereal atoms, of inconceivable energy, constituting the

primæval fund or reservoir of "force." The received theory assumes the ether to have no motion whatever, excepting that impressed upon it by the vibrating molecules of stellar and planetary matter.

And, instead of the analogue of a dynamic gas is so unhesitatingly adopted by Mr. Preston as the type of ethereal constitution, thoughtful physicists have been disposed to accept the suggestion, that the phenomena of "polarization" point rather to a constitution of atoms held in stable equilibrium by intense mutual *repulsion;* and more resembling, therefore, the character of an infinitely attenuated jelly, than of a mobile gas. (Herschel's *Familiar Lectures.* Lect. vii, sect. 67.)

In his preface, Mr. Preston announces that

"The present work, the result of much thought and careful study, is intended to afford an explanation or insight into the mode of working of an important series of physical phenomena at present referred to the theories of 'action at a distance,' and 'potential energy.'" (Pref., p. 1.)

The conclusion reached in this review, is that the author, like all his numerous predecessors, has failed utterly to accomplish his intended object;* and that his proposed "physics of the ether," is really but a travesty of gaseous dynamics under impossible conditions. That his work has been "the result of much thought and careful study," cannot be doubted; adding, however, but one more example of ability misapplied, and of labor entirely thrown away. The author adds: "The first part of the work contains an argument designed to prove that . . . . 'potential energy,' or an energy *without motion*, is inadmissible." (Pref., p. 1.) *Per contra*, no physical phenomenon is better established, than that *Motion* (whether of molecules or of masses), is constantly originating from that which is *not* motion; *i.e.*, from static *position*—as in combustion and explosion; in the galvanic battery; in the equipoised avalanche; in the over-loaded suspension bridge; in the bursting water reservoir. These simple but pregnant facts, outweigh all suppositions; and for such examples

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* A somewhat similar discussion is the subject of a volume entitled "*Matter and Ether:* or, the Secret Laws of Physical Change." by Rev. Thomas Rawson Birks. 12mo. Cambridge. Macmillan & Co., 1862. A much more elaborate exposition of the ethereal hypothesis of molecular Attraction, Gravity, Electricity, Galvanism and Magnetism, will be found in *The Mathematical Principles of the Physical Forces.* By Prof. James Challis, pp. 996, octavo. Published at Cambridge and London, in 1869. Several of the mathematical discussions were published ten years earlier, in the *Philosophical Magazine.*

of reposing power, no better name has yet been devised than "potential energy," or "static force." In short, "motion" is, *in every case*, a mutable resultant; and cannot, therefore, be a primæval "cause." In diametrical opposition to the fundamental kinetic postulate of our author, we announce the inductive thesis, that motion, of whatever form, is *invariably* the progeny of static force.

When Mr. Preston, from his supposed plane of higher wisdom, somewhat magisterially asks: "Can it be said (and if so, in what respect), that a clearer idea admits of being formed, of the *means* by which motion is produced, when it is referred to 'action at a distance,' and when it is referred to 'psychic force'?" (p. 3)—the honest and intelligent student of nature, distinctly avows that he has no idea whatever "of the means," clear or otherwise—certainly no "clearer idea," therefore, in the one case than in the other; and the one action is rejected, while the other is accepted—*solely* as the outcome of a life-long and unbroken induction.

The basis of all real knowledge is experience. If we know that all matter tends to "fall," we know it *only* as a result of universal experience. If we do *not* know why or how this "falling" tendency exists, it is because we have absolutely no experience to guide us. And where observed facts fail to sustain our speculations, or anticipations, there the modesty of true science requires us to frankly confess our ignorance, and to acquiesce in *the simplest statement of the actual phenomenon;* without presuming to venture on metaphysical dogmas as to the possibilities of natural action being measured by the limitations of existing human conception. Should any conclusive evidence be hereafter discovered, that the "ether" itself is a *myth*, then we should be driven to the admission, not only that gravitative influence, but that even vibratory motion is an *actio in distans;* however "inconceivable" the proposition.*

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*Prof. Faraday seemed at one time disposed to accept the idea of pure "force" being capable of exciting vibration, as well as motion. In 1846, he said: "The view which I am so bold as to put forth, considers, therefore, radiation as a high species of vibration in the lines of force which are known to connect particles, and also masses of matter together. It endeavors to dismiss the ether, but not the vibrations." (*L. E. D., Phila. Mag.*, 1846, xxviii, 348.) Light has a known rate of progression, however, so that a ray starting from the Sun, reaches the planet Mercury in 3 minutes, Venus in 6 minutes, our Earth in 8 minutes, Mars in 12 minutes, Jupiter in 41 minutes, Saturn in 1 hour and $\frac{1}{4}$, Uranus in 2 hours and $\frac{1}{2}$, and Neptune in 4 hours. No such *propagation* exists in the case of gravity.

Perhaps no more fitting conclusion to this unduly prolonged discussion, could be made than to select some of the precursors of Mr. Preston in this field, if only to keep him in countenance, though this is scarcely necessary. Almost every year, for the past forty years, one or more essays or treatises have been submitted to the French "Academy of Sciences," designed to offer a full explanation of the origin of force in general and of gravitation in particular. Omitting "electrical," and other more visionary systems of the universe, the following list, taken from the *Comptes Rendus* of the Academy, represents only the announcers of ethereal pressure as the physical catholicon:

Mr. Schweich. "Theoretical Ideas of Gravitation." (*C. R.* 1838, vii, 83.)

Mr. Reichenbach. "On Universal Gravitation." (*C. R.* 1838, vii, 973.)

Mr. Darlu. "Memoir on the Causes on Gravitation." (*C. R.* 1839, viii, 338.)

Mr. De Tessan. "On Universal Attraction." (*C. R.* 1840, xi, 481.)

Mr. Lamé. "On the General Principle of Physics." (*C. R.* 1842, xiv, 35; "Lessons on Elasticity," 1852, xxxv, 459.)

Mr. De Boucheporn. "Researches on Physical Laws." (*C. R.* 1849, xxix, 107; "On the General Principle of the Laws of Astronomy and Physics," 1853, xxxvi, 417 and 533.)

Mr. Guynemer. "On the Impulsion of an Ethereal Fluid." (*C. R.* 1853, xxxvi, 593; 1854, xxxviii, 942.)

Mr. Durand. "A Theory of Gravity and Magnetism. (*C. R.* 1856, xliii, 165.)

Mr. Hermite. "On Universal Gravitation." (*C. R.* 1857, xliv, 330.)

Mr. Allouin. "Hypothesis of the Causes of Universal Attraction." (*C. R.* 1859, xlviii, 269.)

Mr. Nardini. "On the Nature of Cosmic Forces." (*C.R.* 1862, lv, 917.)

Messrs. F. A. E. and Em. Keller. "Memoir on the Causes of the Effects attributed to Universal Gravitation." (*C. R.* 1863, lvi, 530.)

Mr. E. Martin. "On a Substantial Ether, as one of the Grand Principles of Physical Nature." (*C. R.* 1863, lvi, 1211.)

Mr. Renaud. "Hypothesis concerning Universal Gravitation." (*C. R.* 1864, lviii, 202.)

Mr. Kleber. "On Gravitation and Universal Attraction." (*C. R.* 1866, lxiii, 599.)

Mr. Leray. "A New Theory of Gravitation." (*C. R.* 1869, lxix, 615.)

Mr. Lecoq de Boisbaudran. "On the Theory of Weight or Gravity." (*C. R.* 1869, lxix, 703.)

Although many of the above papers are published by title only, they are believed all to announce the discovery of ethereal impulse, or *propulsion*, as a substitute for *tension;* a system foreshadowed a century earlier by the celebrated Lesage. Cf course, this forms but a small portion of the literature of the subject. Let us not presume to anticipate the verdict of posterity as to the scientific merit embodied in this array of neglected genius and unappreciated discovery.

P. S.—In the note on estimates of the probable density of the ether, in the last No. of the JOURNAL, should have been included the following additional reference. Sir William Thomson in 1855, endeavored to compute at least a minimum limit to the density of the ethereal medium, from the quanity of dynamic energy it is known to be capable of transmitting. Taking the value of solar radiation (at the earth's surface) at 83 foot-pounds per square foot, for one second, the number of feet through which the wave-motion has traveled in one second, being about 980 millions, (representing of course that many cubic feet), we should have as the mechanical energy of one cubic foot $\frac{83}{98 \times 10^7}$, or about one 11,200,000th of a foot-pound. If the transverse velocity of vibration be assumed at $\frac{1}{50}$ of the velocity of radiation, and "it appears improbable that it could be more," (about 19,600,000 feet per second) it is estimated by Sir William Thomson, that a cubic foot of the medium should not weigh less than $\frac{1}{156}$ trillionth of a pound (or a little more than one quadrillionth of a grain); which would give the ether a maximum rarity about 2000 trillion times that of ordinary air.

The line of reasoning here pursued is sagacious, and the higher limit of tenuity, apparently well made out. But the actual density of the ether is probably considerably greater than this; since the amplitude of ethereal vibration is from every consideration an extremely small fraction of the wave-length; and the velocity of vibration not likely to be as much as the thousandth part of that of radiation.

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EDITORIAL.

NOTICE.—The publication of the JOURNAL is made under the direction of the Editor and the Committee of Publication, who endeavor to exercise such supervision of its articles, as will prevent the inculcation of errors or the advocacy of special interests, and will produce an instructive and entertaining periodical; but it must be recognized that the Franklin Institute is not responsible, as a body, for the statements and opinions advanced in its pages.

Practical Information for Practical Men.—The general idea that practical information useful to a practical man can be made interesting or instructive to the ordinary reader, is an altogether erroneous one. Admitting that the experienced workman in any position in the scale of productive labor desires information relating to the advances in theory or practice in his particular field of labor or description of product, it must be asserted that as regards both theory and practice he is in his way fully informed already—quite as thoroughly as any general instructor likely to offer to inform him—and he will not tolerate the kind of incomplete description and imperfect reasoning which passes for knowledge to the uninitiated. He demands that his informant shall start from his standpoint and make available his basis of facts and experience in the attempt to communicate that which was hitherto unknown or unappreciated, but it is now essayed to make known and comprehensible.

In one sense, elementary science can be called practical information, and to the school boy or the apprentice it unquestionably is so. A knowledge in elementary science is essential to the practical man or the mechanic; but to the latter the mere reiteration of fundamental principles, however happily clothed in new words, and embellished with striking examples, ceases to be practical information. There are numerous admirable text books, in which will be found collated information in all branches of science—books ranging from the elementary to the most profound treatises on their several subjects—which place before the studious and diligent reader the means for acquiring knowledge in any degree. For those whose ability, inclination or opportunity does not admit the close study which entire comprehension involves, there have been provided hand books of the several trades or callings in industry, and special works on mechanical construction, wherein it is only needful to search to find the facts and figures of usual reference and application. In fact the record of theory and practice in technical pursuits, and especially of mechanical construction, in books, journals, magazines and newspapers, not to omit the same record in patents and circulars, is voluminous and uninteresting in the extreme, except only to those whose daily labor or whose special field of research demands their perusal. On the whole a dictionary is an entertaining book to read through, compared to an encyclopedia of machinery; and a government document of expenditures, of an ancient date, is enlivening, compared to a mechanics' magazine of the same antiquity.

The text books or the hand books may not be all that could be wished by the critical, either in method, completeness or thoroughness, yet any practical man in any field of industry, who studies them, comes to appreciate their deficiencies as well as their merits. His acquired "book knowledge" will lead him to doubt any assertion, as well of fact as of conclusion, when his understanding has not brought him to accept it, without much regard to the authority from which the assertion was derived. Thought, consideration, study, are the price to be paid for information by the best educated and the most practical. It is not possible for the idle, the inconsiderate, or the unthinking to obtain knowledge or an available substitute for it, in nostrums or receipts, from the brief reading of entertaining notices in the newspapers, the popular articles on surprising science in the magazines, or the brilliant experimental demonstrations of the lecture room.

The general public does not understand these propositions and curiously enough, the practical man, when the information set forth in the newspaper, magazine or lecture room is beyond his individual knowledge is as likely to be pleased by scientific fireworks as the rest of the community, while he would decidedly condemn the superficial, misleading statements if they came within the scope of his own information or were applied to his own methods.

There has been a time when elementary information on physics, chemistry or mechanism was "information to practical men," and that time has been a comparatively recent one. Less than fifty years ago the "Society for the diffusion of useful knowledge" was issuing a set of text books in the form of tracts on these subjects. Nowhere else in the English language did the information exist in a form available for self-acquisition; and the completeness, clearness and simplicity of the treatises published by the society have not since been excelled—or in the first regard, completeness—not yet been equaled. These treatises supplied a want in their day, but are somewhat antiquated at this time, and they have been superseded by others on the same subjects which have maintained generally the record of the advance of science, its growth and accretion. There has been a great change in the habits of the English people, and one more marked in the same direction in those of the American half of the family, in the way of careful and studious reading. Fifty years since, the well read Englishman (in English literature) would quote pages from the *Spectator*, or from Locke; from Burke or from Gibbon; from the "Lay" or "Childe Harold,' with little apparent task on his memory, and he read to learn to quote, or to use any book, page and line in this manner. The treatises of the society were written and printed to satisfy such readers, and many such were found. A similar set of related and connected treatises, written up to the most advanced scientific knowledge of the day, would be an excellent addition to our literature, but it is more than questionable if they would find readers and students as of old.

Popular lectures, entertaining descriptions, both oral and written, upon the teachings of elementary, as well as upon the results and phenomena of profound science; presentations and illustrations of facts in chemistry, physics, mechanism or construction, will constantly be repeated; they may gratify the popular taste, but they can never again be practical information for practical men. The standard of

the present and the future is a higher one. He who is a practical man now (or hereafter) must have acquired in the course of his practice an experience in some peculiar direction of knowledge, enough to have compelled him to have learned its "science," regularly and methodically, to have investigated by his reasoning faculties and founded himself upon principles, and not on half comprehended rules.

This process of self-education is an easy one to him who would learn. Possibly there are certain preliminary steps, which it is hard to take if there is a deficiency in primary education. Thus the ability to read and write, and to use the rules of arithmetic and simple algebra are indispensable to the beginner in higher studies, and this ability is difficult for the untaught mind as a self-acquisition. Allowing that there are practical men who do not possess this ability, or are deficient in their arithmetic and algebra (as is sometimes pleaded), so that they cannot study the text books, or use the hand books; and that for them, practical information should be prepared. Such an allowance implies :—Only, that he who is incapable of understanding the text books or hand books, so far as they refer to his calling, is equally incapable of judging as to the truth or error of the assertion of the writer or lecturer, upon whom he is supposed to rely. To such a one, unless his informant were infallible, it were better that he should not be *informed* at all. There is no royal road to learning; its acquisition without study is like the acquisition of wealth without labor. It is as necessary for the mechanic to study out his problem when it comes to him to be studied, as it is for him to finish his task by his handicraft.

There are those who teach a different doctrine. Some who have known better, have courted notoriety, popularity, and profitable reward, by advertising the easy method of learning without effort. The art of popular scientific lecturing is understood to consist in demonstrations, which every one can comprehend, accompanied with assertions supported by *satisfactory* experiments. It seems to have become the peculiar assumption of the half informed man, that he shall use his eloquence, if not his ignorance, in instructing those who are not informed at all. But the really practical man appreciates these things. How many times he will have read or listened to an account of an apparatus, process, or product, with which his knowledge is complete, and known the whole to be fraudulent or erroneous?

The course of lectures unquestionably occupy a place in the system of education—enlivening, illustrating and elucidating the studies from the book. Even the desultory lecture serves its end in giving general information and intellectual entertainment. It does its part, and a large one it is, in forming an intelligent, if not a thoroughly informed community. A great end is subserved if some persons are educated to appreciate knowledge. The popular magazine, or the popular science of the newspapers, in the same way answers the same purpose. But all this knowledge is ephemereal and of little value to the practical man.

The progress and advance of the arts and sciences are positive facts. Hand in hand, the one or the other, art or science, leads. With the multitude of thinking artisans, art most frequently goes before where science follows, but in the end, under the direction of other artisans, or in other fields, science gives the permanent guidance for art, and the "ample page, rich with the spoils of time," unfolds to each successive generation what their ancestors so laboriously acquired. Thus enlightened, it is the progress and advance of the arts and sciences, not the arts and sciences themselves, that the practical man needs information about.

The action of the managers of the Franklin Institute, from the organization of the Institute to the present time, has been consistent with the views now expressed. For the purposes of education of those who needed it, they established courses of lectures on scientific subjects, which have been maintained to the present time. In the origin of the Institute it was probably supposed that the instructive element would predominate more largely in its proceedings than has actually occurred. School education on the same topics has become so universal that the later generations do not need, nor do they take much interest in such lectures as commanded crowded and attentive audiences years ago. Still a measure of interest is kept up in the same class of teaching, which each generation must repeat and acquire for itself, and the popular lecture at the Franklin Institute is yet somewhat more than an entertaining pastime.

But in the labors of the Institute the founders and subsequent managers pursued, as practical men, another direction. Take two striking instances in the early history of the Institute—the inquiry into the law of the expansive force of steam, and that into the cause of boiler explosions. Knowledge on these subjects, above all others,

is necessary information for practical men, but then the investigation was tedious, the discussion was recondite, and the concluding results were unintelligible, almost incomprehensible, to any others than practical men in an extremely limited kind of practice. All the early proceedings of the Institute, as published in the JOURNAL, exhibit the same direction; and for the JOURNAL itself, the standard adopted was, that it should be made the record of the advance of science and the arts, rather than merely educational and popular. There is found on its pages, therefore, the briefest of allusion to the classes of study, courses of lectures, and of current events; but instead of these, are given the most thorough and elaborate reasoning and formula that might be required to support and demonstrate each or any scientific development. The reputation of the Franklin Institute as established by its JOURNAL in the earlier years, in marking the successive strides in arts and science for fifty years, is deservedly one to be proud of.

This reputation the present editor has endeavored to maintain, but he is fully aware that it is at a cost of popularity. If there are now, at this present time, many more writers on scientific subjects, and much more novelty evolved, than when this JOURNAL came into existence, there are also yet more "scientific" publications, so that the "offerings" to the JOURNAL are not so numerous as of old. Much that is now written appears in newspapers, and although grains of wheat exist, yet the chaff predominates in the loose literature from which the wheat is to be selected; if such selection be made at all, by more than editor's skill. It follows that the task of securing good, practical articles is not an easy one.

But the point in issue is the one relating to the popularity of practical information, and, at the risk of some self laudation, it can be well exemplified by the past year's articles in the JOURNAL. Take the article on quadruplex telegraphy, which is a description in the simplest language, by a practical man, giving to any other practical telegrapher a clear and comprehensive account of the novel procedure. That upon Determination of Roof Strains, which is a practical exhibition of a method which all roof constructors should learn, for the ready, simple and accurate understanding of their work: That upon Chimneys for Steam Boilers, which gives a table covering all usual chimneys for stationary engines, and formulæ which will apply to all others: That relating to the theory of lenses, which supple-

ments previous theories by those which have come to be understood as applied to the lens of the photographer or the microscopist of to-day: That on trials of expansive and non-expansive engines: Other papers which have appeared during the past twelve months might be quoted, all of which, without exception, have the least possible interest, *except* to practical men; but they are of the highest importance to them. It might be claimed that, practically, it would have answered the same purpose if all the reasoning, computation and formula which formed the bulk of these articles had been omitted. And this is partly true, if it is to be assumed that the editor of the JOURNAL was an infallible judge of each article, or the author above scrutiny, and no further dictum than mere placing of results before readers was necessary. Such unqualified confidence is not to be supposed, and the sole alternative is to present for consideration all the data and processes of treatment by which the conclusions were attained, and challenge examination and criticism.

Finally, it may be asserted that there is an incompatibility now and for all time, between practical and popular information.

The Pennsylvania Museum and School of Industrial Art.—*Report of J. B. Knight, Trustee, in behalf of the Franklin Institute June* 21, 1876.—This association was first organized, as you are probably aware, about a year ago, "to establish for the state of Pennsylvania, in the city of Philadelphia, a museum of art in all its branches and technical applications, and with a special view to the development of the art industries of the state."

The plan of organization provided that several institutions and corporate bodies of the city and state should be represented in its board of trustees. Among these is the Franklin Institute, and in January last you did me the honor to elect me to represent the Institute in said board.

The charter obtained under the statutes of the commonwealth, was approved by the court on Feb. 26th last, and the permanent organization of the association was completed immediately afterward by the election of officers and adoption of by-laws.

One of the first things done by the preliminary organization was to secure the permanent use of Memorial Hall after the close of the exhibition, and this is assured by the authorities having the control of the building.

In the meantime efforts were made to obtain subscriptions to its fund, with considerable success, and this has been pushed more vigorously since, until there has been secured about $40,000. With this fund the committee on selection have made considerable contracts of purchase, and have secured many valuable and desirable articles.

The selections for purchase were made with the view of cultivating a correct taste in the art of designing and decorating, and to show as far as possible the styles employed in different ages and countries, avoiding repetition as far as possible, and in no case were articles selected because they were merely curious.

In addition to the articles purchased, several valuable ones have been presented by the makers, and several of the commissions in charge of government exhibits have indicated that we may expect some very desirable gifts from their collections.

Your representative has been made the chairman of the committee on the *mechanic arts*, and has made such efforts as are within his power to secure drawings and models of such works in civil and mechanical engineering as will illustrate the most advanced state of these arts, as well as something of their history.

One has but to study the influence such institutions have on the industries of a people, even in the most cultivated nations, to realize the great importance this one must be to us; and as we find foreign as well as American institutions competing with us in the purchase of articles, it is believed that Pennsylvania is not a day too soon in its efforts to establish this museum on a firm basis.

In the accomplishment of the object in view money is needed, in raising which all can assist by becoming contributing members, and paying $10 per year, or a life member by paying $100 at one time, or by subscribing larger amounts, each additional $100 of which entitles such member to an additional vote at the annual election. Several subscriptions of $5000 have been received. No better investment can be made by those who are able, to take their dividends, in increased comforts, improved tastes, and increased prosperity of their country.

The Franklin Institute as a body and its individual members, have ever been foremost in promoting and fostering the educational interest of our city and state, and it is to be confidently hoped that similar assistance will be extended to this important branch of technical training, and for the establishment of which this seems to be the proper time.

Report of the Committee of Science and the Arts on the Dioptric Light of Gen. M. C. Meigs.

HALL OF THE FRANKLIN INSTITUTE,
Philadelphia, September, 1875.

The Sub-Committee of the Committee of Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred for examination the improved "Dioptric or Water-light," invented and patented by Gen. M. C. Meigs, U. S. Army, report that they have examined the same, and consider the arrangement of the bracket tubing with a swing joint adapted to the curve of the glass water globe, and through which the gas passes to the burner, as very meritorious; thereby securing such movement of the burner around the globe. as to enable the concentrated rays of light to be thrown upon any desired spot, or limited area of space.

The use of glass globes, or bowls filled with water as condensers of light, has long been practiced by mechanics, artisans, and others, but

generally in very crude portable forms. The patented combination of its use in this instance is so very neatly and permanently adapted to any of the present styles of illumination, that its introduction to a great variety of purposes, would seem to be secured thereby :—

The glass globe being an enclosed one, with the exception of a small filling hole at the top, renders the fluid not subject to any agitation, or the admission of any dust or other impurities, which would materially affect the transmission of the refracted rays of light passing through the water; as also retaining its transparency, preventing much evaporation, and keeping it serviceable for months without replenishing. In these respects it is greatly superior to the "water bowl," which rapidly accumulates dust, and is subject to disturbances of the fluid, by currents of air passing over it. For a comparison of its light, *with* and without the glass globe, a very careful test was made on a "Bunsen Photometer" of 100″ scale made by the American meter company. The test was made with the fish-tail burner furnished with the bracket, consuming *five cubic feet of gas per hour*, at a pressure of *nine-tenths of an inch* column of water—and the same *elements* existing during the whole time of the test. The results are as follows, and expressed in standard candles, consuming one hundred and twenty grains of sperm per hour. With the globe attached the light concentrated upon the screen of the photometer gave a result of 90·75 *candles*, in the centre of a field of illumination of 3 or 4 ft. diameter—*without the globe attached*, the light from the same burner, gave a result of 16 candles upon the screen of photometer. It must be remarked in explanation that the light of the area of said illuminated field, is restricted to the focal dimensions, due to the diameter of the globe; and was not diffused throughout the apartment, as was the case during the tests without the globe. It is therefore to be distinctly understood, that, for all the purposes to which this invention may be applied, such as reading, writing, drawing, engraving, etc., etc., the strength of light is materially increased only within the concentrated rays of the globe condenser. As a basis of economy, taking the quantity of gas consumed as 5 cubic feet per hour, and equal to 16 candles, giving a reasonably satisfactory light to whole apartment, *without the globe*—and *with the globe* we have the same quantity of gas consumed per hour and a light concentrated upon an area of 2 sq. ft. of 90·75 candles, or 28·35 cubic ft. of gas per hour.

MEMORANDA OF TEST.

	With globe.	Without globe.
Gas consumed per hour	5. c.ft.	5. c.ft.
Pressure of gas	·9 inches.	·9 inches.
Distance gas from screen . . .	90·5 "	80· "
" candle " " . . .	9·5 "	20· "

For the intensity of light, the photometric formula is : As the squares of the respective distances—

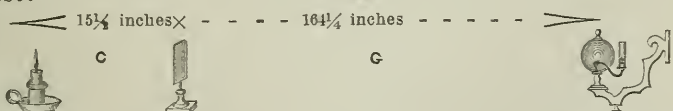
With globe. $\frac{2)90{\cdot}5}{9{\cdot}5} = \frac{8190{\cdot}25}{90{\cdot}25} = 90{\cdot}75$ Without globe. $\frac{2)80}{20} = \frac{6400}{400} = 16$ candles.

Respectfully submitted :

(Signed) Henry Cartwright, *Chairman.*
Samuel Sartain.
Joseph Zentmayer.
Sub-Committee.

Dioptric Light.—The following abstract from a communication from General Meigs on the subject of his light, taken in connection with the report of the Committee of Science and Art, will explain itself. "The results obtained by the committee (although highly favorable in comparison to the ordinary gas light) are so much below those which were obtained at the Gas Inspector's office in this city (Washington, D. C.), when I was present, that I sent a note of the test:—

Distances.



Candle. Screen. Dioptric Light.

Test of the Meigs dioptric light, with gas jet, burning five cubic feet of gas per hour, of 16 candles power, in comparison with a standard sperm candle at the U. S. Gas Inspector's office in Washington, D. C.

The screen of translucent glass being placed as on the cut, so as to exhibit an equal illumination on each side, the distance $C = 15\frac{1}{2}$, and $G = 164\frac{1}{2}$:—The candle burnt at the rate of 132 grains per hour in place of 120 grains per hour, which is the *standard* quantity for comparison:—The Argand burner consumed at the rate of 4·75 cubic feet per hour, in place of 5 cubic feet per hour, which is the standard quantity:—The gas was tested to be 16 candle gas by another observation.

COMPUTATION.

$$\frac{G^2}{C^2} = \frac{27060 \cdot 25}{240 \cdot 25} = 112 \cdot 60 \times \frac{132}{120} \times \frac{5}{4 \cdot 75} = 130 \text{ candles.}$$

That is, the value of the beam of light equals that of 130 standard sperm candles, or 8·12 standard Argand burners (each of 16 candle power).

I have since, with rude apparatus fitted up by myself, compared the results of a five foot Argand burner to the effect of a six foot fish tail burner which I prefer, and now use exclusively. (The committee had a five foot burner, and I suspect it was not adjusted to the best focus.)

A six inch globe has a focal length for parallel rays of three inches. But for illuminating we do not need a parallel beam, but a somewhat divergent one, so as to give an illuminated field of considerable extent, without a sharp image for the flame, and between astigmation and dispersion of the rays to produce a diffused light, devoid of flicker or unequality. I find that the proper position for the jet is with its flame perpendicular to the axis of the divergent beam and tangent to a sphere $4\frac{1}{4}$ to $4\frac{3}{8}$ inches radius, *i. e.*, its centre to be $1\frac{1}{4}$ to $1\frac{3}{8}$ inches distant from the surface of the globe. If further off, or nearer, the field is not sufficiently illuminated.

The six foot burner, while it gives the more satisfactory light, is *not* the most economical, by some small difference in the resulting effect, but the light is sufficient for reading a newspaper at a distance of 20 feet with ease, and at 10 to 15 feet it thoroughly illuminates the paper on a draughtsman's drawing board. Of course, most of the obnoxious difficulty from heat, upon the person using the light, is avoided.

A New Steam Carriage.*—A vehicle has lately made its appearance in the streets of Paris fully deserving the name of "steam carriage," for it moves freely and easily through streets and squares, turns the sharpest corners, stops, turns aside, or goes in the same pace with a row of cabs and omnibuses, along bridges and thoroughfares. This carriage is constructed by M. Bollée, civil engineer, of Mans, for his own use. It weighs, with water and store of coals, but without passengers, nearly 4 tons; with twelve passengers, about $4\frac{3}{4}$ tons, which weight is distributed on the four wheels of the carriage as follows:—The two driving-wheels, of a diameter of 3·87 ft. and a thickness of 4·7 in., which are behind, have to sustain a weight of nearly $3\frac{1}{2}$ tons; the front (steering) wheels, of a diameter of 3·12 ft., the remaining $1\frac{1}{4}$ tons. The latter are com-

* From the *Builder*, London, April, 1876.

pletely independent of each other, and may be altered at will by the driver, who here supplies the place of the coachman, for guiding the carriage. The driving-wheels, although they are on a common axle, are not keyed to it, and receive their movement each from a pair of cylinders fixed between the wheels, and driving in the first place an intermediate axle, from which the movement is transmitted by means of a chain to the respective wheel.

The cylinders have a diameter of 4 in., and a stroke of 6·3 in. They are provided with Stephenson's link-motion, and the supply of steam is regulated in such a manner that in turning a curve it may be shut off entirely from the pair of cylinders on the inner side of the curve.

The boiler, finally, which is at the end of the carriage, is constructed on Field's system, vertical, with 194 tubes of 1·06 in. outer diameter, has a diameter of 2 ft. 7½ in., and a height of 3 ft. 3 in. All the parts are of the best materials, and made as light as possible, which accounts for the slight weight of the carriage. The consumption of water (according to the *Comptes Rendus*, p. 762) is 132 gallons per hour, if fully loaded, and at a speed of 9·3 miles per hour. At that rate, the consumption of coal is 176 lbs. per hour, which compares favorably with that of other street locomotives.

Note upon the Direction of Currents in a Crowd in Open Air.—At the gathering of people on the occasion of the opening of the Centennial Exhibition on the 10th of May, 1876, a striking example and illustration was observed of the fact that a crowd lives only by aid of the ascending current from the bodies of the persons composing it. The observer was sitting on the platform in front of Memorial Hall, and all the space between this platform and the Main Building, a space of probably 150 feet in width by 500 feet in length (of dense crowd), was occupied by about 40,000 persons, standing as closely as comfort would allow. The air was quite warm, about 75° Fah., and a light breeze was blowing from the west. There were many smokers in the crowd, and it was noticeable that the course of tobacco smoke, which showed white against the brown front of the Main Exhibition building, indicated the course of the current at different points. A breath of smoke on the outskirts of the crowd was dispersed irregularly. A puff of white smoke anywhere towards the middle of the crowd rose with great apparent rapidity until it was lost to sight by ascending above the line of roof of the building; the background of white clouds, with which the blue sky was then broken, not allowing it to be distinguished higher up. The swiftness with which the smoke rose showed that the ascending current in the centre of so thickly thronged and so large a space, was rapid. In fact it showed a set of currents like those at a fire—on the outskirts tending towards the centre, in the centre upwards. M. C. M.

Civil and Mechanical Engineering.

ON THE CIRCULATION OF WATER IN STEAM BOILERS.

ADDRESS BEFORE THE

AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION,

at their Meeting in Philadelphia, June, 1876.

By Robert Briggs, C. E.

Mr. President and Gentlemen:—I am much gratified by the honor conferred upon me in being requested to address you upon the subject of the phenomena attending the ebullition of water, and with the risk that I may be reciting facts well known to all, and certainty that what I shall say will be merely elementary, I venture to quote a portion of a lecture delivered by me before the Franklin Institute, trusting that a new view of old facts may not be out of place.

The three forms of matter—solid, liquid and gaseous—are incident to some definite quantity of heat which accompanies each form, which is known as the latent heat, and varies in amount for the different substances. For water, which is the substance under consideration at this time, the latent heat added to and absorbed in the change of form from ice at 32° to water at the same temperature, is 142°·65 (Person), and in the change of form from water to steam of 32° is 1,092° (Regnault). But the sensible temperature of a liquid at which it will vaporize is found to vary with the pressure (or tension) of the vapor above it, and the tension of steam at 32° is only 0·085 lbs. per square inch, while the pressure of the atmosphere is 14·7 lbs. per square inch. Ebullition or free boiling of water does not take place under atmospheric pressure until the water is heated up to 212°, at which point the tension of steam is equal to the usual atmospheric pressure of 14·7 lbs. per square inch, and the latent heat of change of form from water at 212° to steam at the same temperature, is 966° (Regnault).

The other properties of water, as regards heat, with which we have to do in considering the circulation in a boiler, are its expan-

sion and its rate of conductivity. Water expands (on being heated) at anomalous rates: about 0·8 per cent. from 40° to 100°, about 3·9 per cent. from 40° to 200°, about 8·7 per cent. from 40° to 300° and about 11·5 per cent. from 40° to 350°. The conductivity of water is exceedingly slow (as it is in all liquids when not in motion), so slow that it can be assumed to be absolutely non-conducting in the present inquiry. As a consequence of this non-conductivity of water, it can only be heated by the application of heat below, and by transfer and diffusion of the state of heat by means of the motion of the particles of the fluid mass; and uniformity of temperature is attained in such a mass only by continual circulation.

The usual and accepted method of heating water, therefore, is by placing it in a vessel, to the under side of which, heat is applied, which heat is transferred through the material of the vessel and imparted to the water. The film of water in contact with the inner surface of the vessel, at the place where its outer surface is exposed to the fire, becomes heated and expands and mixes with the water immediately near it, until a stratum of water is formed which is lighter than the mass of water above it and tends to float, and its flow being supplied instantly by heavier water, a circulation is commenced. After the establishment of a circulation of slow velocity, acceleration goes on, until at some rate of movement, the friction of the currents of water against the sides of the vessel or against themselves (for eddies, whirlpools and cross-currents will form in a vessel under such circumstances) offers a resistance to greater velocity, exactly equal in amount to the disturbing force of the expanded water in trying to rise. The slow run of first movement with gradual increase of velocity and circulation, arises from the fact that particles of water are, in common with those of other bodies, either solid, liquid or gaseous, subject to the laws of the application of force; whereby they do not commence to move until some resistance is overcome, nor do they cease to move until the acquired momentum is compensated. So long as the heat imparted to the water is below the boiling point, a circulation of hot water can be urged with perfect quietness in properly formed vessels, and in tubes, until an equilibrium of temperature of the water in the vessel, or tube, is established; and when the heat of the water is abstracted in the course of circulation, a high velocity of current can be attained, and great quantities of heat can be transferred without disturbance of flow.

But as the boiling point approaches, another train of conditions is brought to bear, which may be better considered by referring to the accompanying figure.

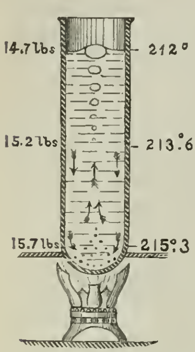


Fig. 1.

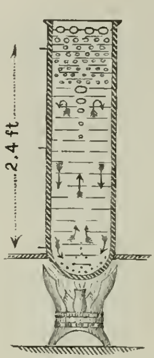


Fig. 2.

Fig. 1 represents a vessel containing water exposed to the action of a fire upon or under the bottom of a vessel. It is supposed that the depth of water in the vessel is 2·4 feet, when it would follow, as the weight of a cubic foot of water at 212° is very nearly 60 lbs., that the pressure of the column of water at the bottom of the vessel is very nearly one pound per square inch. The relations of pressures and of temperatures of ebullition, in this column of water are: at the surface there will be the pressure of the atmosphere = 14·7 lbs., with its corresponding temperature of ebullition = 212°; at the depth of 1·2 feet the pressure will be 15·2 lbs., and the temperature of ebullition = 213°·65; and at the bottom, at the depth of 2·4 feet, the pressure will be 15·7 lbs., and the temperature of ebullition 215°·3.

The effect of the application of fire to the bottom of this vessel having first been admitted to raise the temperature of the entire mass of water to 212°, and having expelled most of the air which was absorbed in the water at its normal temperature before heating, will next be extended to the formation of steam as the means of dispersing the constant addition of heat; and somewhere in the height of the column, a point will be reached where the rate of circulation will permit the return water from the top surface, which will inevitably have the temperature of 212°, to reach the bottom where it will be heated, let us say, to 213°·65 by the fire.

The specific heat of water compared to that of iron is very great (about nine times as great), and a film of water of the same thickness as a sheet of iron, with which it may be in contact, has a little the greater capacity for heat; but the rapidity of convection of heat in water is far greater than that of the conduction in iron, so the general temperature of the water in contact with the iron is maintained with the smallest excess of temperature of the iron.

The extreme tenuity of the gases of combustion, although they have about twice the specific heat of the iron by weight, reduces the relative quantity of heat, by volume, in contact with the bottom of the boiler to such an extent that the external temperature of the iron where exposed to the fire, may, for ordinary practice, be taken as that of the water within the boiler. Still, notwithstanding the great rapidity of convection, the first result from the intense heat of a flame is to create numerous exceedingly small vesicles of steam (represented by dots on Fig. 1) in contact with the internal surface, which float away from it, and in a short distance are absorbed into the water again, giving out their heat to the water of lower temperature. With active firing these small vesicles will form a turbid cloud, and the closing up of the vesicles, and contact of water with the bottom, will produce a characteristic singing noise which attends boiling, and is particularly noticeable just before the boiling point is reached, when the water at the bottom may be a little above 212°, while that of the mass above may not have attained that temperature. In the case which has been supposed, where the temperature of the ascending current is to be 213°·65, after this cloud of vesicles is absorbed, which will occur within two or three inches of the bottom, the water will become solid again, and rise to the height of 1·2 feet before the pressure upon it will have become sufficiently reduced to allow a bubble of steam to form.

At this height evaporation should commence; it will, however, not do so, because the heat is completely disseminated in the water, and because water has considerable adhesive force or strength of itself (although the particles move upon or slide over each other with much ease, they offer a positive resistance to being separated, which, by the laws of thermodynamics, is measured by the latent heat absorbed), and the water will hold together even when agitated by currents and eddies, as shown in Fig. 1, until relieved of 1 to 2-10ths of a foot more of column pressure; it then begins to exhibit, first a turbidity of small vesicles of steam intermingled with the water, which, ascending with the current and agitated together, will, by joining, form small bubbles of steam. These bubbles will have their internal atmosphere of steam, and their internal surfaces are free to give out steam to this little atmosphere, and these little bubbles, which began to form under about 15 lbs. pressure, will augment in size as the pressure is relieved, at the same time that they are grow-

ing from the formation of steam from the water surrounding them until this formation of steam will have reduced the temperature of the surrounding water to 212°, when the bubbles, and the water enclosing them, will have reached the surface.

Thus, while the circulation was produced by the levity of the column (the heated water), it is greatly promoted and accelerated by the presence of steam in bubbles in the heated mass, and the value of this agency of bubbles can be estimated as follows: A pound of water at 212° is very nearly 28·8 cubic inches or 1-60th of a cubic foot, while a pound of steam at the same temperature is 26·36 cubic feet in volume, or 1,580 times as large as the water from which it was made. The case supposed in Fig. 1 gives 1°·65 of heat as being expended in making steam from what was solid water at the depth of 1·2 feet of 213°·65 temperature. The latent heat of steam at 212° is 966°, and consequently the 1°·65 will make (when applied to a pound of water) 1-580th of a pound of steam, the volume of which will be 26·36-580ths of a cubic foot, or 1,580-580ths = 2·7 times the volume of a pound of water; and the mixed volume of bubbles of steam and water which will come to the surface at the temperature of 212° will be very nearly 3·7 times as great as the volume of water which was solid at 213°·65, lower down in the vessel, and the entire volume of mixed steam and water, above the point of the first formation of steam, will be 2·35 times that of the original water at 213°·65.

Perhaps it may be well to exhibit some rate of evaporation in conjunction with the supposed ebullition, and this can be done by comparison with the ordinary rate of firing of a stationary boiler, which is from 10 to 12 lbs. of coal per square foot of grate per hour, and as each pound of imperfectly consumed coal, on such a grate, yields 9,000 to 10,000 units of heat only, the total efficiency of a square foot of grate becomes 100,000 to 108,000 units of heat per hour, equal to about 30 units per second. If it be assumed that the surface of evaporation be equal to that of the grate, and that either equals one square foot, the volume of steam which will be evolved per second will be 0·8 cubic foot, whence 1-1975th of a pound of water must be converted to steam each second for each square foot of grate, or of surface of evaporation, or, in terms of the volume of water, 0·9 cubic inch of water will be evaporated to steam, and 8-27 of a cubic foot (532 cubic inches) of water will be circulated and part with its

heat each second. Thus it is evident that while the motive power to promote circulation is very great; the usual conditions of a boiler, with a restricted area of surface for evaporation, demand intense activity of circulation. (An example of higher temperature than 212° will be considered further on.)

While this current of steam and water is ascending, a corresponding quantity of water which has lost its heat must descend, and unless provision is made to separate these currents, the conflict will add to the disturbances occasioned by the formation of bubbles. In a vessel or a boiler of considerable dimensions of width as compared with its depth, the conflict will take care of itself, and the velocity of circulation, induced from the expansion of volumes of the heated and partially evaporated mass, will establish a *regime* or equilibrium of action, in the transfer of heat from the fire surface on the one hand, and to the formation of steam on the other; and the steam bubbles will appear at that point in the column of water where the equilibrium may require them as agents for acceleration. If the water surface at the top of the vessel be not large enough (a not very unfrequent occurrence) for the steam to evolve itself in the course of a quiet circulation and surface evaporation; or for the bubble below the surface to develop in size without interfering with the return circulation from the top, it will then be found that a secondary circulation, under pressure from a column of foam, will have been established (Fig. 2), and the supply of return water for the bottom will be derived from below the evaporating surface. The heated return water thus supplied will be again heated at the fire surface to a point higher than before, and the point of elevation where bubbles begin to form will be depressed, to correspond to the elevation of temperature. The bubbles will then develop and approach the surface laden with steam of higher temperature than would be sufficient to preserve a more quiet circulation, and will escape from the surface with some violence; of course a condensation into the disturbed particles of water will ensue, and the result will be the establishment of a strata of foam on the top of the legitimate circulation, and the passing off with the steam of a large quantity of water in the form of mist. This action can go on increasing in violence (with the intensity or extent of surface of the fire as compared to the volume or depth of water to which the fire is applied, taking into account the means of circulation provided) until the return water comes back to the

point of application of heat—the fire surface—at such a temperature, that the amount of heat, there supplied, will generate a bubble of steam at once; when, at this moment, the circulation is interrupted by the tendency of such a bubble to rise within the return current; the next effort of the steam is to eject the mass of water within the vessel convulsively.

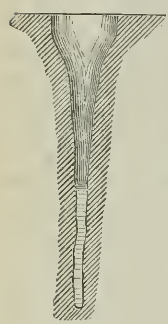


Fig. 3.

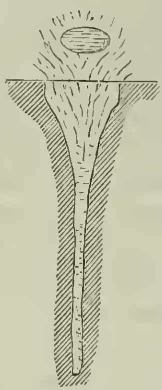


Fig. 4.

This phenomena is that of the Geyser (Figs. 3 and 4). In this natural exhibition of a defective water circulation in a heated vessel, the sides of the Geyser tube or vessel are heated as well as the bottom—a condition incident to various steam boilers—and the vessel has a funnel shape, which is not so usual in boiler construction. In the normal state of a Geyser, or a mass of water in the small end of a natural funnel, is in active ebullition from volcanic heat at the bottom, (the constant supply of water being maintained by the dripping of springs in the upper part of the cone quite near the earth's surface); and at or near the time of an eruption, the boiling water is in, or close upon, an equilibrium of circulation and ebullition. By throwing sods, or substances of about the same specific gravity with the water, down the hole, the circulation is impeded, and a quantity of steam of greater pressure than what is due to the column of water is formed, until the mass of water is lifted from the bottom, and the bubble of steam thus evolved at the bottom will augment from the water surrounding it, especially as the piston of water above it, gains in diameter and diminishes in thickness (as the funnel increases in size) *thus reducing the pressure upon the inclosed steam.* The heat of the bottom and walls of the tube will expand the volume of inclosed steam, and evaporate with great celerity the spray or such small quantities of water as may trickle down, and the two causes will preserve the pressure of the steam, beneath the water, to the point necessary for the production of the phenomena, notwithstanding the increase of volume. An eruption of much violence will follow—the whole column of water being expelled with great force, accompanied by the evolvement of steam from the mass of water in the air above.

After the ejection, the fountain of water will have given out a large part of its heat; and if the time of exposure to the air were long enough, the temperature of the ball and spray would fall below 212°, while the Geyser tube would have been entirely relieved from pressure by the expansion and escape of the inclosed steam, so that the mass could fall back into the heated chasm. But not only will scarcely time enough have passed for the water to have divested itself of heat, but the mass which falls will be a broken shower of intermingled steam, air and water; and also the internal surfaces of the tube will have attained, from the absence of water in contact with them, a very high heat, which will be given out to the first small quantities of water which return, generating a large volume of steam, without loss of heat in heating water; and several successive discharges will occur before such degree of quietness is reached, as will allow the water to remain within the funnel; and even after this, much turbulence will be exhibited before the regime of circulation will produce a stable condition of movement.

In my examples, Figs. 1 and 2, the phenomena of ebullition have been shown at the atmospheric pressure, and although it is not intended at this time to carry this discussion beyond the mere elementary exhibitions, yet it may be well to make a similar sketch and computation at higher temperatures.

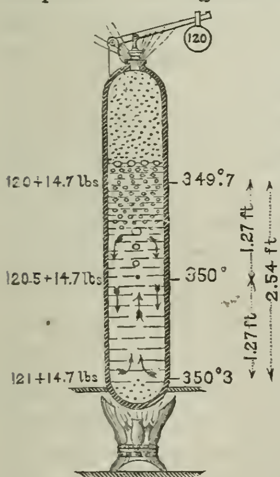


Fig.5

Fig. 5 represents a vessel containing water exposed to the action of heat similar to those shown in Figs. 1 and 2 (ante), except that a permanent pressure of 120 pounds per square inch above the atmosphere is maintained, under which the generation of steam is supposed to be going on. In consequence of the expansion of water at higher temperature, the height of column which represents one pound pressure now becomes 2·54 feet (in place of 2·4 feet), and in consequence of the properties of steam, the difference of temperature corresponding to one-half a pound pressure per square inch becomes 0°·3 (in place of 1°·65). The other figures change as follows: The latent heat at 349°·7 becomes = 870° (in place of at 212° = 966°). A pound

of water has a volume of 30·9 cubic inches (in place of 28·8); a pound of steam has a volume of 3·3 cubic feet (in place of 26·36). The volume of steam as compared to the water from which it is formed at 349°·7 is as 185 to 1 (in place of at 212° as 1,580 to 1). The mixed volume of steam and water at the surface will be but 1·06 times that of the solid water at 1·27 feet below, while the total column of mixed steam and water above the solid water is 1·03 times that of the solid water in this case (in place of 2·35 times at atmospheric pressure). It will be seen from this that the tendency to foam, falls off rapidly as the pressure at which evaporation is permitted, increases—when the bubbles cease to be so large an obstacle to the return circulation; and also that the motive power for circulation gained by the levity of the steam bubbles, falls off with increase of pressure. The manifest effect of this deficiency in inducing circulation, will be to move the point at which the bubbles will begin to form nearer to the fire surface (lower down in the vessel), and to *define the dimensions* of the streams of rising and returning currents. If the rising current is small enough, the bubble of steam may begin to form on the very bottom of the vessel, rise up enlarging in magnitude to the surface, enveloped all the while in a column of water of (in this supposed case) 350°·3 temperature at the bottom—enlarging by relief of pressure, which acts in two ways; first, by permitting expansion, and second, by causing evaporation into its (the bubble's) atmosphere, and finally, the bubble of steam is evolved at the top, quietly at 349°·7.

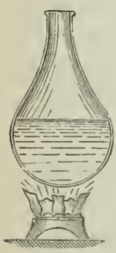


Fig. 6.

There are two other phenomena of boiling which should be stated here. The first of these is to a great degree experimental. If water is carefully heated in a nicely-formed vessel, Fig. 6, [first taking the precaution to boil it, so as to expel the air which all water absorbs into its volume in quantities relative to the temperature (diminishing with their increase)], applying the heat so as to preclude any disturbance in the course of circulation, the temperature can be elevated much beyond the boiling point without the commencement of ebullition. Mr. Knight, the Secretary of the Franklin Institute, has succeeded in reaching a temperature of 247° in an open vessel, which indicates an internal tension for the water of about 14 lbs. per square inch. Of course the commencement of evaporation under these cir-

cumstances is a convulsive ebullition. The presence of a little broken glass or of particles of any material of splintery form, will prevent the phenomena; and the introduction of any sharp object will almost certainly incite ebullition whenever the boiling point is exceeded.

This peculiar property of heated water seems to be the equilibrium of cohesion (before referred to), which is here manifested to the extreme of instability. The conditions by which it can be displayed are so limited that they cannot be regarded as having a possible existence in any steam boiler, in which there is not the least probability of elevation of the temperature of the water above the boiling point (at any given pressure) by securing that quiescence which all experiments have shown to be demanded for the production of this result.

The second phenomena bears a more important relation to the steam boiler. It has already been shown that water will leave a heated surface, so soon as the temperature of the entire mass has reached that degree where the increment of heat imparted at the surface, upon which it should be brought in contact, will elevate the temperature above the boiling point properly due to the pressure from the mass; and it remains to be stated how a similar repulsion can exist without the temperature of the repelled mass of water being elevated in like degree. If we suppose a heated surface, so hot and so well supplied with heat, that its *radiant heat* will generate steam, from the under surface of a mass of water, of greater tension than the subsisting pressure of the atmosphere or inclosure, together with the pressure proceeding from the weight of the mass, the mass itself will be repelled from the heated surface, and will float upon the vapor emitted. The familiar example is a drop of water upon a flat-iron; the philosophical

Fig. 7.

one is that represented by Fig. 7 and is known as an exhibition of the *spheroidal* condition of water. Water supported in this way must be evidently in very unstable equilibrium, and with the slightest inclination of the heated surface would roll on its vapor to the lowest point, and a capsule or saucer-shaped vessel is therefore indispensable to retain it.

In the course of the experiment very little heat is imparted to the ball of water, the radiant heat being spent mainly upon the under surface, while that which passes through this surface shines through the water as light shines through glass; thus, only the film, so to speak, of the under surface is heated, and much if not most of this heat upon

the surface is at once expended in generation of steam. The little heat that is imparted to the water at the under surface, in place of establishing a circulation of water within the ball, simply disturbs the centre of gravity, and induces the whole mass to roll over and allow its heavier (colder) side to find its equilibrium at the bottom; and in the operation, under the conditions stated, a spheroidal shape is assumed by the body of water.

Investigations have shown that when the surface of the vessel is heated to about 380° Fah. a spheroid of water of about two inches of thickness will be repelled and constantly supported, while the temperature of the water (with the air in a summer-hygrometric condition?) will be about 206°, or 6° below the boiling point (Boutigny).

This recital of what constitutes the spheroidal condition (so-called) of water has been made, with so much explicitness, in order to render it apparent that it is merely a simple consequence to the laws of transmission of heat from a surface to water, and not an occult property in any sense. The statement of importance in boiler construction is, that at some temperature a heated surface will repel water, and that once repelled the surface will cease to impart as much heat as before, and the repelled mass of water can become of much lower temperature than it must have had if the contact had been preserved, and these truths apply to water under pressure (atmospheric or other), and to any height of column of water upon or above the heated surface, a relative temperature being accepted for the various conditions.

Whenever the water has been once repelled from a fire surface or plate, the temperature of that surface will increase with great rapidity, and the limit of this temperature of a plate it is difficult to fix. It is certain that where there are gaseous bodies on either side of a plate, the temperature of which bodies are known, the temperature of the plate itself will be a function of the capacity for heat of the two gaseous bodies in opposite contact; but even this complex law for obtaining the heat of a plate from which water has been repelled fails in the case of the fire-box of a boiler, where half the heat from the flame is radiant heat which is absorbed into the plates of the fire-box at an unknown temperature of intensity, although the quantity of heat may be well established. But I think it safe to assert that in less than one minute's time the temperature of a 5-16 inch plate in a fire box from which water has been repelled, will become over 1,000°

Fah., and the plate will be materially reduced in strength to withstand the internal pressure.

I have not attempted to complete this application of principles to the locomotive boiler; in fact, I feel the deficiency of my elementary remarks in their want of comprehensive statement of circulation, where the return takes place from the back instead of downwards, as I have discussed; but I present these considerations as showing the direction of inquiry to be followed in the attempt to account for failures of fire-box sheets or of tubes, whenever the evidence of overheating presents itself. In such cases, I have little question that obstructed circulation and inadequate water-space have more to do with accidents than the quality or nature of the material of the plates. . . .

Mr. Briggs quoted an instance of the failure of some tubes in a class of locomotives constructed ten or twelve years since, for the Illinois Central Railroad. In this case, a cluster of seven 2-inch tubes, which were located about one foot down. upon the tube sheet, in its middle, in several engines of the same class, collapsed about one to two feet in front of the sheet. A sample of one of the collapsed tubes, which was furnished the speaker by Mr. Hayes of the Illinois Central Railroad at the time, showed a cup-shape introversion without rupture of about six inches in length, the upper side of the tube having been depressed into the lower one completely. Of course the tube had been above red heat when this occurred. The remedy was understood to have been the removal of one or two vertical rows of tubes to allow the water to circulate.

Notes on Ventilation.—Some experiments made recently by Theron Skeel, C.E., and Mr. Carl. W. Nason, at Doct. Hall's church, New York City, have given the following resulting performances of a ventilating fan :

	Number of Experiment. I.	II.
Revolutions of fan per minute	66·7	110·
Difference of atmospheric pressure between inlet and outlet chambers, in inches of water .	0·145	0·400
Velocity of air in duct beyond the fan, in feet per minute, as indicated by an anemometer .	484	750
Cubic feet delivered per minute . .	9900	15370

The Fan* employed is of the kind most generally in use in ventilation of buildings in the U. S. at the present time, having been first introduced at the U.S. Capitol at Washington, in 1857 (the earliest in use was, during the same year, at the Academy of Music, Philadelphia). It is a disc upon a shaft, with blades attached upon one side, and extending to the outer periphery, rotating in front of a circular mouth or opening in a wall, or fan-side. The mouth or opening is either directly from the external air, or from a passage of ample size which leads therefrom, and the ring of discharge at the periphery of the disc is open for the escape of air in all directions to the "*air chamber*," in which the disc revolves. From the air chamber a "*duct*" is lead to the points of distribution or delivery of air in the building.

This Fan is 7 feet in diameter of disc—8 inches wide at the tips of the blades; 5 feet in diameter of mouth—15 inches width of the blades at the mouth; having $\frac{3}{8}$ inch clearance between the edges of the blades and the wall or fan-side; with an area of 19 square feet at the mouth, and 15 square feet at the periphery (the actual area for passage of air at the tips of the blades when delivering maximum quantity = 10·9 feet only), while the area of the duct or passage leading from the air chamber is $20\frac{1}{4}$ square feet.

It is nearly impossible to connect the observed pressure of the column of air derived from a ventilating fan, with the velocity or corresponding quantity of air passing through it. Were the fan entirely at rest, and the passages leading to it, as well as the duct leading from it, open, the whole being in the basement of a building which is heated in any way; there would be sucked through it, without the indication of but the slightest difference of pressure between the inlet and outlet "chambers," a quantity of air varying with the difference of temperature without and within the building, the height of the building, the resistance of the ducts and registers of delivery, and the freedom allowed for escape of heated air at the top of the building. The only reliable standard of measurement of effect or efficiency, is the anemometer, to be applied as a test under the differing conditions of the season or atmosphere. The purpose of a fan in ventilating of buildings, is to insure a definite supply of air at all times, with a satisfactory distribution in all parts of a room. In

* A full description of this species of fan will be found in the Proc. Institution of Civil Engineers. Vol. XXX. 1869-70. Part II, pp. 276, *et seq.*

cold weather its function is to measure out the supply, and place the building under such pressure that no leakages of cold air at cracks shall occur. In more moderate and warmer weather its end is to establish a circulation which would otherwise become dormant. The quantity of air resulting from a given velocity will be found to vary materially with conditions external to the fan itself.

Referring to experiment No. 1, when 9900 cubic feet of air was supplied, it is stated that at the end of a service of $1\frac{1}{2}$ hours, with 1400 people in the church, there was found to be a proportion of $C\,O_2$* in the air, of $12\frac{1}{2}$ to 10,000. The audience room which was thus supplied, had a capacity of nearly 480,000 cubic feet of air. If it be supposed that the air in the room was fresh, and had the normal quantity of $3\frac{1}{2}$ parts of $C\,O_2$ per 10,000, it is possible to verify, or at least compare the result with the usual allowance for vitiation of air by the occupants. The 9900 cubic feet per minute for 90 minutes give 891,000 cubic of air supplied. This was expelled at the beginning of the session as fresh air, with $3\frac{1}{2}$ parts of $C\,O_2$ per 10,000, but became vitiated to $12\frac{1}{2}$ parts per 10,000 at the end, whence the expelled air carried away $\frac{891000}{10000}\times\frac{12\frac{1}{2}-3\frac{1}{2}}{2}=401$ cubic feet of $C\,O_2$. The 480,000 cubic feet of contents of the room had also been exchanged, until it contained $12\frac{1}{2}$ parts of $C\,O_2$ per 10,000 in lieu of of $3\frac{1}{2}$ parts of $C\,O_2$, when it had acquired $\frac{480000}{10000}\times(12\frac{1}{2}-3\frac{1}{2})=432$ cubic feet. The total of $C\,O_2$ which had been produced by the respiration of 1400 people in one a half hours, equal to 2100 people in one hour, is $401+432=833$ cubic feet $C\,O_2$.

∴ The respiration of each person per hour = 0·4 cubic feet $C\,O_2$. The best authorities give 0·5 to 0·6, and this result is in quite satisfactory correspondence, when it is considered that much carbonic acid may have been diffused at leaks and cracks at the doors and windows, and much more at the passages of efflux, where it would flow out more rapidly than the current of escaping air. Beside, the allowance of 0·5 to 0·6 per individual is an average of persons in moderate exercise, in place of at rest in a room.

Accepting the 833 cubic feet as the quantity of $C\,O_2$ emitted by the 1400 persons in $1\frac{1}{2}$ hours, and applying the computation in the reverse way to experiment II, it would follow that 10·6 volumes of $C\,O_2$ per 10,000 would be the resulting vitiation. Good theoretic ventilation would assume 56,000 cubic feet of air per minute as *desirable* for 1400 people.

* $C\,O_2$ is the chemical notation for carbonic acid gas.

GAS WORKS ENGINEERING.

By Robert Briggs, C. E.

[Continued from Vol. cii, page 40.]

"The '*hydraulic main*' is a long trough-pipe, with a covered flat top; it is about two feet wide and three feet deep, and runs the whole length of each *setting*, resting over the front part of it. The leg of the bridge-pipe (∩), which joins the cover of the hydraulic main, enters into it for half the depth, or one and a half feet, and is called the '*dip-pipe.*' The hydraulic main is permitted to fill a little more than half full of tar and ammoniacal liquor (mostly tar, as the ammoniacal liquor runs out first over the bridge at the end of the hydraulic main), and the end of the dip-pipe is thus immersed (*sealed*) by the tar, from one-half inch; and any gas which passes up the stand-pipe, over the bridge-pipe and down the dip-pipe, must bubble up through one-half inch to one inch of tar, to get into the upper part of the hydraulic main. The chief purpose of the hydraulic main is to prevent an escape of gas backwards, down the stand-pipes, when a retort-lid is removed; and this purpose is affected by the pressure of the gas in the hydraulic main, which, pressing on the liquor outside of the dip-pipe of an open retort, lifts up a column on its inside, and stops off the flow of any gas; but the stand-pipes and the hydraulic main answer the further purpose of a hot condenser, giving time enough and surface enough for most of the tar to separate out of the crude gas in them, in place of going over to be cooled together; when the tar would be likely to extract the luminous gases or vapors, very completely. Beside, the first oils which are made in the beginning of the process of distillation are condensed in the stand-pipe, and run back into the retort to be destructively distilled afterwards.

"There collects in the stand-pipes, and runs down at the last end of the process, a small quantity of stiff tar, which lodges in the bottom of the mouth-piece; this is usually collected (scraped up) and put into the next charge of coal. Some of this coal tar had been thrown out with the coke on the occasion of one of my visits to the gas-works, and produced at the coke-heap the characteristic odor.

"[§ § *Two.*] At the Market street works, the tar and ammoniacal liquor are conveyed, from the ends of the six hydraulic mains by pipes

nowhere open to the air, into a large tar-well, which is a vat formed by a liquor-tight cellar of one of the buildings used for storage of lids, castings, and materials of various kinds; the floor, which forms the cover or top of this vat is brick arches, covered by iron braces. This vat seemed to be about fifty by eighteen feet, by seventeen feet deep, inside measure, and in it these offensive by-products are thoroughly and satisfactorily isolated. The tar having settled and become free of ammoniacal liquor, is then removed by a steam-pump, and taken across, as wanted, to a temporary building, in which is placed some distilling apparatus for recovery of the oils and separation of the pitch.

"Upon the whole, this coal-tar distillery apparatus and its mode of working appeared to me to be quite satisfactory. Some of the vats ought to be closed better than they now are, and some other precautions should be taken to prevent nuisance of smell from spilled oils; but I must regard this treatment on the spot to be far more likely to remove causes for complaint than any mode of removal possible to make. I think it would be impossible to convey the tar away by pipes or otherwise, without the risk, and almost certainty, of greater annoyance to the public than now exists.

"At a distance of twenty feet from the tar-building no distinctive odor was perceptible to the nostrils (which, however, had their power of smell vitiated to some degree by the odor of naphthaline and ammoniacal liquor obtained at the condenser-house).

"The ammoniacal liquor was said to be drawn off from above the tar and used afterwards in washing the gas, and will be referred to again in the course of this statement.

"[§ § *Three.*] The gas is now taken from the hydraulic mains by large pipes (sixteen inches in diameter, I believe), and these pipes pass down under the ground into one large main pipe of thirty-six inches diameter, which passes underground, also, to the house for condensing and washing the gas, and by suitable branches and connections supplies the gas—first, to three '*condensers*' and afterwards to three '*washers;*' all the outlets from the washers being joined again into a thirty-six inch main-pipe, which proceeds over to the 'purifiers.'

"The condensers are long and high constructions (or boxes) of cast iron, with pilasters and architectural ornamentatation, and measure about thirty-six feet long by five feet wide on the floor, by

thirteen to fourteen feet high. These condenser boxes are altogether closed up, and are in three separate parts horizontally; there being one flat plate partition about one and a half feet from the bottom and another about one and a half feet from the top, leaving eleven feet for the height of the middle part. In this middle part are stood up, between and joining together the flat partitions, a large number (it is said two hundred and eighty-eight to each condenser) of pipes, which are thus each eleven feet in length, and they are four inches internal diameter; and, as water-tight joints are made between the bottom partition plate and the ends of the pipes, the middle part can be, and is, filled with water, which surrounds the upright pipes. The top and bottom spaces (above and below the pipe ends) are, also, divided by cross partitions, so that when the gas enters at the bottom at one end of a condenser it will pass up thirty-six of these upright pipes and down the next thirty-six, and so on until its gets to the end of the series, when it will pass out to the main pipe leading to the washer.

"It follows that in this passage of the warm gas, in contact with the cooled sides of the pipes, it will be cooled itself, and will have had the ammoniacal liquor nearly all condensed, and the most of the floating tar will have been abstracted. The liquor runs down into the bottom of the lower division of the condenser, and is from thence drawn off by suitable drips.

"It was formerly customary to arrange a condenser with pipes exposed to the open air; but a much greater extent of surface was needed to effect the same purpose, and the condensation was imperfectly done in hot weather and overdone in cold weather, when the cold ammoniacal liquor would absorb the luminants from the gas. The 'water-surface' condenser here used, is in accordance with the best established practice of to-day.

"The liquor is led away by pipes to some vat or tank, but at the condenser-house of the Market street works the drips or seals are either open, or by some neglect the liquor is permitted to be exposed to the air, and the odor of various gas effluvias is excessively offensive, and disseminates all over the place and beyond the limits of the works.

"Comparing this condition of things with what I found in similar establishments in New York last week, I can state that at the Manhattan or New York Mutual Gas-works only the slightest odor in the condenser-room was to be perceived.

"After the gas leaves the condenser, it goes next to the washer. The washers are boxes of similar external appearance to the condenser, only that they are about two feet less in external height, and measure about three and one-half feet in width. The internal divisions differ from those described for the condenser entirely, being merely a number of vertical plates, which divide each washer into thirty-six upright spaces, so that the gas can go up one and down another alternately, until it has passed up and down the whole length of the washer. In each of these spaces are placed one or two jets, which generally discharge little streams of water upwards, and in its descent as a rain, picks up and absorbs the ammoniacal vapors and washes them away. The water of washing is, in such cases, usually discharged into a sewer or stream. In place of using water for the jets at the Market street works, the ammoniacal liquor which separates from the tar, together with that condensed in the condenser, is now pumped up to a vat and used for this purpose. It is clained that this water will sufficiently purify the gas from ammonia, and that it can be used over and over, until it acquires a suitable strength to be treated for manufacture of commercial ammonia product. I am not prepared to deny the possibility of this result, but am also not prepared to believe it, as it is not in accordance with any practice which I have ever seen, and from the behavior of gas delivered in my own residence, I do not think the gas as well purified from ammonia as it might be, although certainly not very imperfect in this respect. It is recognized by all gas-makers that the use of much water impairs the luminous efficiency of gas, quite as much as the removal of ammonium compounds improve it, and it is consequently the practice of intelligent managers to use as little water as possible. To effect this purpose, the most approved practice demands a shelf-washer; which is an arrangement of high boxes in which shelves are placed overlapping each other; upon these shelves the water is trickled, so as to keep the entire surface wet, and the gas is made to zigzag up the tier of shelves; several repetitions of this practice are followed, and the gas is worked with a minimum quantity of water.

"Notes taken by me at the Pagoda Works of the Birmingham and Staffordshire Gas Company, Hugh Young, manager, in January, 1870, describe the 'washer in use there, for twenty-four inch mains, to be six compartments, six feet square by sixteen feet high, each with six shelves; fresh water is used in one of these compartments, which is

pumped over and over for three hours, when it is changed to the next compartment, and so on until, at the end of eighteen hours, the liquor will have attained the requisite density of manufacturing purposes. The washing was followed by two small purifiers, sixteen feet by sixteen feet, with sawdust damped with weak sulphuric acid, one of which was changed each three weeks, and the ammonia tests, for constant exposure of one month duration, were exhibited and shown to be perfect.'

"This example may be accepted as the best usage of to-day in the United Kingdom for treating gas for ammonia.

"At the Market street works, all the ammoniacal liquor, after passing through the washers and being concentrated, is now run into tanks; and again elevated so as to form a head for the flow through pipes under the streets, to the chemical laboratory of Henry Bowers, on Washington avenue, about one mile distant. This arrangement was said to have been effected for the first time six months since, and, except some objectionable exposure of the liquor at the works, is much better than wasting this vile compound into the river, as was formerly practiced. Of course the utmost care is demanded that the pipe used for conveying it shall be positively tight and free from leaks.

"The pipes and connecting branches about condensers and washers are provided with numerous stop-valves, which admit of such control as will direct the gas through any of them, or 'by pass' them all, as desired.

"All the buildings and apparatus described to this point are located on the square of ground north of Market street and west of Twenty-fourth street, with the Schuylkill river for the western and Filbert street for its northern boundary.

"[§§ *Four.*] The gas after leaving the washer is carried by a thirty-six inch main-pipe across the line of Market street, below ground, in the thoroughfare under the eastern span of Market Street Bridge (which crosses above the wharf and yard level of the gas-works), and is conveyed to the purifying houses; the latter being located about half-way between Market and Chesnut streets, near the river. At the northern side of the purifiying house are placed engines and exhausters for moving the gas. These were not examined by me, but I am disposed to think that they differ in no essential way from the same parts of gas apparatus in other works.

(To be continued.)

CONTINUOUS GIRDERS AND DRAW SPANS.

By A. Jay DuBois, C. E., Ph. D., Prof. Civil and Mechanical Engineering, Lehigh University, Bethlehem, Pa.

[Continued from Vol. cii, page 32.]

V. EXAMPLE OF PIVOT SPAN.

In Fig. 7 we have represented a draw, the two outer spans being each 40 ft., the centre span $B\ C = 20$ ft.; centre height at B and $C = 10$ ft.; end height, 6 ft.; panel length, 10 ft. Two systems of triangulation, as shown in the Fig. We take the live load at 1 ton per ft. per truss, or 10 tons at each apex. Dead load we assume *one-half* of this, or 5 tons per apex. Our proportions are, of course, taken for the sake of illustration merely, and not as an example of actual practice. All the points necessary to be brought out are, however, illustrated as well as by a much longer span and more usual proportions.

As to the construction of the truss, it is to be observed that the end verticals must take compression only, and *not tension*. This is easily effected in practice, and is necessary to prevent ambiguity as to the way in which the strains may go. A negative reaction (downward), or end shear, might otherwise cause either tension in 12 and compression in F, or else tension in 15 and compression in 56 and tension in A. If, however, 15 cannot take tension, we have but one course for the strains and the problem is determinate. For similar reasons also, we must construct the centre span so that the diagonals take *tension only*, and the three verticals *compression only*. All other pieces may take both tension or compression indifferently. These points as to construction being settled, we proceed first to determine the reactions.

1*st*. *Reactions*.

We shall consider the case of the *tipper*, or secondary central span, as this case, we will suppose, approaches most nearly the true state of things. The method for four fixed supports is, of course, precisely similar, only taking the formulæ already given for that case. The less the span $B\ C$ the nearer the case approaches to that

of three fixed supports, and where $B\,C$ is zero, or n is zero, the formulæ are the same as for two equal spans.

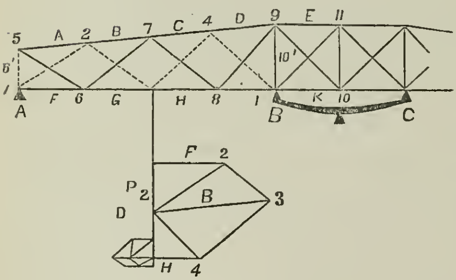
We must first put our formulæ into proper shape for use in the particular case under consideration. Thus $l = 40$, $n\,l = 20$, hence $n = \frac{1}{2}$ and $H = \frac{35}{4}$; $k = \frac{a}{40}$ where a has for each apex load the successive values 10, 20, 30, etc., for $P_1\,P_2$, etc., or k is successively $\frac{1}{4}$, $\frac{2}{4}$, $\frac{3}{4}$. Our equations are then, after reduction.

$$R_A = \frac{5}{35}\,[70 - 73\,k + 10\,k^3],$$

$$R_B = R_C = \frac{5}{35}\,[45\,k - 10\,k^3],$$

$$R_D = \frac{5}{35}\,[10\,k^3 - 17\,k],$$

FIG 7



Now the denominator of k is always 4, of k^3 always 64; the numerator only changing according to the position of the weight. These equations can then be written:

$$R_A = \frac{1}{224}\,[2240 - 584\,a + 5\,a^3],$$

$$R_B = R_C = \frac{5}{224}\,[72\,a - a^3],$$

$$R_D = \frac{1}{224}\,[5\,a^3 - 136\,a],$$

where a has the value 1, 2, 3, etc., for $P_1\,P_2\,P_3$, etc.

These, then, are the practical formulæ for the present case, and from them we can easily find the reactions for the apex loads of 10 tons each.

Thus for P_1 we make $a = 1$ and find at once $R_A = 7{\cdot}415$ tons $R_B = R_C = 1.58$ and $R_D = -\,0.584$ tons.

For P_2, make $a = 2$ and then $R_A = 4{\cdot}964$, $R_B = R_C = 3{\cdot}035$, $R_D = -\,1{\cdot}035$.

For P_3, make $a = 3$, and $R_A = 2{\cdot}78$, $R_B = R_C = 4{\cdot}22$, $R_D = -\,1{\cdot}22$.

Loads upon the span BC we suppose to rest directly upon the turn table. For the first load to the right of C, *viz.*, P_4, the reactions at A and B are the same as for P_3 at D and C already found. For the next load P_5, reactions at A and B are the same as for P_2 at D and C. For P_6 at A and B, same as for P_1 at D and C, etc. We thus know the reactions at A and B, due to every apex load in either end span, and can now proceed to find the strains. The formulæ for reactions, it will be observed, are very simple for any particular case.

2*d*. *Calculation of Strains.*

We have only to apply the method of moments, and the work is so simple, that an example or two will suffice. Conceive a section entirely through the truss, which cuts only three strained pieces. Take the intersection of two of these as a centre of moments. Then the moment of the strain in the third must be balanced by the sum of the moments of the known exterior forces, such as loads, reactions, etc.

Take P_1 for example; its upward reaction at A is 7·415, [a negative reaction acts *down*. Thus for P_4 the reaction at A is $-1·22$. The minus sign indicates that the reaction is down, and that, neglecting the dead weight of girder, it must therefore be held down there. The tendency is to rise]. Now take a section through A. It cuts four pieces. But since the weight P_1 acts only through its *own system of diagonals* (full in Fig.), only these are strained. The point of moments for A is then at 6, *the intersection of the other two strained pieces.* The strain then in $A \times$ by its lever arm $= 7·415 \times 10$. The lever arm of A with reference to 6 is from the proportions of the figure, easily found to be 6·965, hence $A \times 6·965 = 7·415 \times 10$, or $A = 10·64$ tons *compression* because the upward reaction, acting to revolve the section round apex 6, tends to compress A. This strain evidently acts through both A and B, since both these flanges are included by the diagonals of the system for P_1. Hence $B = +10·64$ tons also. Again, for flanges C and D, 78 is the strained diagonal, 8 the point of moments, and the same reaction acts now with lever arm of 30 to cause compression in C and D, while the force P_1 itself acts with lever arm 20 to cause tension. We have then $C \times 8·955 = 7·415 \times 30 - 10 \times 20$ or $C = D = 2·5$ tons compression.

Now we come to the centre span, and must carefully observe the following points. Since D has been found compression for P_1, diag-

onal 89 must be in tension. If there were no vertical strut at B, we should then have compression along diagonal 9 10. But this diagonal by construction *cannot take compression;* it therefore does not act, and the strained pieces cut by a section through E are then, E, K and B 11, which gives us the centre of moments for strain in E at B. Observe, that without the vertical, we should have had 10 for the centre of moments; or even *with* the vertical, had D been found in tension, as may often happen, 89 would have been compression. There would in that case have been no strain in the vertical, since it cannot take tension, and we should then have 9 10 strained and the centre of moments, therefore at 10. Attention to the above is necessary in order to properly pass from the span A B into the middle span.

We have then for strain in E, since R_B passes through the centre of moment B, and therefore its lever arm is zero, $E \times 10 = 7{\cdot}415 \times 40 - 10 \times 30$ or $E = -0{\cdot}34$. The minus sign indicates tension, since the moment of P_1 overbalances that of the reaction. If the centre of moments had been at 10, we might either have taken the moments of R_A, P_1 and R_B, or, what is the same thing, the moment *of the shear just to the right* of B alone.

The lower flanges are found in precisely similar manner. The centre of moments for G and H is 7, and hence $G \times 8 = - 7{\cdot}415 \times 20 + 10 \times 10$ or $G = - 6{\cdot}04$, and so on.

For the diagonals we have only to take the intersection of the upper and lower flanges as a centre of moments for each, and find the lever arm for each. This intersection is, of course, easily found from the known proportions of the figure. Thus 4 : 40 : : 10 : 100. It is therefore 100 ft. left of B, or 60 ft. left of A. For any diagonal, as 34, we find the angle with the horizontal nearly 42°. Its lever arm is then 80 sin 42° = 53·5 feet.

For the weight P_2, for instance, the reaction at A is 4·964 tons, P_2 being 10, and we have, then, strain in $3\,4 \times 53{\cdot}5 = 10 \times 80 - 4{\cdot}964 \times 60 = +502{\cdot}16$. The resultant rotation is then positive, that is from left to right. If the truss were cut through at C and H then, the point 3 would sink, and 4 rise, and 3 4 is therefore in tension, and $= \frac{502{\cdot}16}{53{\cdot}5} = - 9{\cdot}38$ tons. This is sufficient to illustrate the calculation of strains. We have only to remark that in practice, having found the reactions, we can easily *diagram* the strains for each apex

load, as shown in the figure, and check our accuracy by calculating the last flange thus found. This may often save much labor in long spans, in the finding of lever arms, angles of inclination, etc. (See for this method of diagram, "Graphical and Analytical Determination of Strains in a Roof Truss," in April number of this JOURNAL. Also, "Elements of Graphical Statics.") This method of diagram may of course be applied to the continuous girder also.

We can now tabulate the strains for each apex load in every piece.

3*d*. *Tabulation of Strains.*

Thus for flanges—bridge shut—we have:

	A	B	C	D	E	F	G	H	I	K
P_1	+10·64	+10·64	+2·5	+2·5	−0·34	0	−6·04	−6·04	+0·34	−1·34
P_2	0	+12·74	+12·47	−0·14	−0·14	−7·1	−7·1	−5·32	−5·32	+2·14
P_3	+3·9	+3·9	+9·31	+9·31	+1·12	0	−6·95	−6·95	−1·12	+1·88
P_4	0	−3·1	−3·1	−4·88	−4·88	+1·74	+1·74	+4·06	+4·06	+1·88
P_5	0	−2·6	−2·6	−4·4	−4·14	+1·46	+1·46	+3·45	+3·45	+2·14
P_6	0	−1·4	−1·4	−2·34	−2·34	+0·83	+0·83	+1·95	+1·95	+1·34
Total Strains in Flanges	+14·54	+27·01	+24·28	+11·81	+1·12	+4·03	+4·03	+9·8	+9·4	+9·38
		−7·1	−7·1	−11·76	−11·84	−7·1	−20·1	−18·3	−6·4	−1·34

From what has been already said, no difficulty can be found in finding the strains due to the *dead load* (5 tons per apex) *when the bridge is open*.

	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*K*
Thus	0	—6·2	—17·4	—31·2	—40·0	+3·6	+9·7	+20·1	+33·8	+40·0

If now, we suppose the centre supports *raised*, so that the ends just bear, then these strains act *even when the bridge is shut*. The live load strains then act in combination with these, and it is therefore easy to find the maximum strain which can ever occur in any piece. It is also easy to deduce directly from our tables the strains due to any other loads, such as snow, etc., without calculation, by simply taking proportional parts of the apex load strains already found. The complete calculation of a draw span offers, then, no special difficulty, whether we treat it as three spans, as *tipper*, or as two spans. The above includes then, in brief, every case of draw span or of con-

tinuous girder over level supports, and we can now pass on to our general formulæ, upon which the data for all these calculations depend.

VI. GENERAL FORMULÆ FOR SHEARS AND MOMENTS.

The following formulæ include every case of level supports, whatever the number or lengths of spans, for a load anywhere in any span, or for a load uniform over whole of any one span. They were first deduced by Mansfield Merriman, C.E., Assistant in Civil Eng., in the Sheffield Scientific School of Yale College, and are, as we shall see, wonderfully compact, simple and comprehensive. They give us, as already shown, exactly what we need in any case, viz., the outer forces, and in such a condensed form that the engineer can copy them upon a couple of pages of his note-book. If, then, he understands the simple method of calculation already noticed in Article 3, he can solve with ease and perfect accuracy problems which have hitherto been considered "impossible by reason of their complicity," and as "tasking the powers of the best mathematicians."

1. *Notation.*

It is of course essential to be thoroughly familiar with the notation adopted, and the following should therefore be noted with care:

We denote the whole number of spans by s, hence the whole number of supports is $s+1$, numbered from *left to right.*

The number of *any* support in general, always from left, is m. When a load is in any span, the *supports of that span* are always r and $r+1$, left and right.

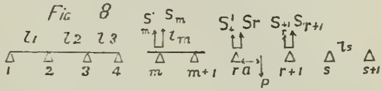
The length of any span is denoted by l, with a subscrit showing what span it is. Thus, l_1 l_2 . . . l_s, l_m, l_r, are, respectively, the first, second and last spans, any span in general, and the loaded span.

A concentrated load is indicated by P; its distance from the nearest *left* hand support is always a; the ratio of a to the length of loaded span l_r is k, or $k = \frac{a}{l_r}$.

Moments and shears are denoted, like lengths of spans, by subscrits. Thus, M_m is any moment depending on the value of m. M_r and M_{r+1} are the moments at ends of loaded spans. The shear to the *right of any support* is S, thus S_m, S_r and S_{r+1}. The shear just to the *left* of any support is indicated by a prime. Thus S_r and S'_{rx1} are the shears just to right and left of left and right supports

of loaded span, Other symbols which we use, as in the preceding Article, we have already used the letter H, for expressions which occur frequently, will be best explained as we have occasion to introduce them. By reference to the following Fig. 8, the reader can familiarize himself with the above notation, and will then find no difficulty in understanding and using the following formulæ. The correctness of these formulæ he must take "on faith." For their demonstration we refer him to the "Elements of Graphical Statics." He can also check them by deducing the various special cases given in most works upon Theory of Flexure, such as "beam fixed horizontally at one end, supported at other," etc., as will be explained hereafter. A few simple experiments on a small scale may also be easily made, and will serve to give confidence in the practical accuracy of the formulæ.

Fig. 8



2. *Formulæ.*

(*A.*) *Shear at any support, right and left.*

For the *loaded span*, we have on the right of the left support

$$S_r = \frac{M_r - M_{r+1}}{l_r} + q,$$

and on the left of the right support

$$S'_{r+1} = \frac{M_{r+1} - M_r}{l_r} + q',$$

where $q = P(1-k)$ for a concentrated load, and $q = \frac{wl_r}{2}$ for a uniform load, w being the load per unit of length, and $q' = P\,k$ for concentrated, and $q' = \frac{wl_r}{2}$ for uniform load.

For an *unloaded* span at the right of any left support whose number counted from the left is m, we have

$$S_m = \frac{M_m - M_{m+1}}{l_m},$$

and at left of any right support,

$$S'_m = \frac{M_m - M_{m-1}}{l_{m-1}}.$$

The "*reaction*" at any support is $R_m = S'_m + S_m$.

These formulæ for the shears are perfectly general and very simple. In general, we need to know only the shear at right of any support,

viz., the left support of the span in which the strains are required. By substituting the proper value for m or r, we can then find the shear, *provided we know the moments at two successive supports.* The whole case then reduces to finding the moments themselves.

(*B.*) *Moment at any support.*

To find the moments, we make use of certain auxiliary quantities represented by A, B, c, and d, whose values we shall give afterwards. The general expressions for the moments themselves are

when $m < r+1$,

$$M_m = c_m \frac{A\, d_{s-r+2} + B d_{s-r+1}}{l_2\, d_{s-1} + 2\,(l_1+l_2)\, d_s};$$

when $m > r$,

$$M_m = d_{s-m+2} \frac{A\, c_r + B c_{r+1}}{l_{s-1}\, c_{s-1} + 2\,(l_s+l_{s-1})\, c_s};$$

now, for the auxiliary quantities, we have $A = P\, l_r^2\, (2k - 3k^2 + k^3)$, and $B = P l_r^2\, (k - k^3)$ for *concentrated load*, where k is always $\frac{a}{l_r}$, and $A = B = \frac{1}{4} w\, l_r^3$ for uniform load of w, per unit of length entirely covering any span l_r.

Also for c and d we have the following values:

$c_1 = 0.$

$c_2 = 1.$

$$c_3 = -\frac{2\,(l_1 + l_2)}{l_2}.$$

$$c_4 = -2\, c_3 \frac{(l_2 + l_3)}{l_3} - c_2 \frac{l_2}{l_3}.$$

$$c_5 = -2\, c_4 \frac{(l_3 + l_4)}{l_4} - c_3 \frac{l_3}{l_4}.$$

and so on, for as many as may be desired, or generally

$$c_m = -2\, c_{m-1} \left(\frac{l_{m-2} + l_{m-1}}{l_{m-1}}\right) - c_{m-2} \left(\frac{l_{m-2}}{l_{m-1}}\right).$$

$d_1 = 0.$

$d_2 = 1.$

$$d_3 = -2\,\frac{l_s + l_{s-1}}{l_{s-1}}.$$

$$d_4 = -2\, d_3 \frac{l_{s-1} + l_{s-2}}{l_{s-2}} - d_2 \frac{l_{s-1}}{l_{s-2}}.$$

$$d_5 = -2\, d_4 \frac{l_{s-2} + l_{s-3}}{l_{s-3}} - d_3 \frac{l_{s-2}}{l_{s+3}}.$$

and so on, for as many as may be desired, or generally

$$d_m = -2\, d_{m-1} \frac{l_{s-m+3} + l_{s-m+2}}{l_{s-m+2}} - d_{m-2} \frac{l_{s-m+3}}{l_{s-m+2}}.$$

For *all spans equal*, these numbers c and d become equal and are successively 0, 1, —4, +15, —56, +209, —780, etc., alternating in sign and each one equal to four times the preceding minus the next preceding. These are the well known "Clapeyronian numbers,"

the properties of which were first made known by *Clapeyron* (*Comptes Rendus*, 1857). They are, it will be seen, merely particular cases of the more general expressions above, first deduced by *Merriman*, and which hold good for *any* lengths of spans.

VII. EXAMPLES OF USE OF THE FORMULÆ.

1. *A girder continuous over three equidistant supports A B and C, has a weight P in first span at distance a from left end. What are the moments? What are the shears at the supports?*

Here we have $s = 2$, also $r = 1$, and $l_1 = l_2 = l$, hence $d_1 = c_1 = 0$, $d_2 = c_2 = 1$, $d_3 = c_3 = -4$, $d_4 = c_4 = +15$, etc.

We have then for the moments, $M_1 = 0$, since $c_m = c_1 = 0$, $M_2 = d_2 \dfrac{Ac_1 + Bc_2}{lc_1 + 2(l+l)c_2} = \dfrac{B}{4l} = \dfrac{Pl}{4}(k - k_3)$ and $M_3 = 0$, since $d_{s-m+2} = d_1 = 0$. For the shears, therefore, $S_r = S_1 = S_A = \dfrac{M_r - M_{r+1}}{l} + q = \dfrac{M_1 - M_2}{l} + P(1-k) = \dfrac{-M_2}{l} + P(1-k)$, or $S_A = \dfrac{P}{4}(4 - 5k + k^3)$, or putting $k = \dfrac{a}{l}$, $S_A = \dfrac{P}{4l^3}(4l^3 - 5l^2a + a^3)$ precisely the same as already given for this case in Art. 4.

For S'_B, we have $S'_2 = S'_{r+1} = S'_B = \dfrac{M_2 - M_1}{l} + q' = \dfrac{M_2}{l} + Pk = \dfrac{P}{4}(5k - k^3)$.

For S_B, we have $S_2 = S_{r+1} = S_B = \dfrac{M_2 - M_3}{l} = \dfrac{M_2}{l} = \dfrac{P}{4}(k - k^3)$. Now the *reaction* at B, or $R_B = S'_B + S_B = \dfrac{P}{4}(6k - 2k^3) = \dfrac{P}{2}(3k - k^3) = \dfrac{P}{2l^3}(3l^2a - a^3)$, precisely as already given. For S'_C we have $m = 3$, or, $S'_C = S'_3 = \dfrac{M_3 - M_2}{l} = \dfrac{-M_2}{l} = -\dfrac{P}{4}(k - k^3) = -\dfrac{P}{4l^3}(2l^2a - a^3)$, just as already given. The pivot span is thus but a particular case of our general formulæ.

2. *A girder of three spans, two end ones equal, has a load at a distance a from left end, what is the shear at left end?*

Let the two end spans be each nl and middle one l. Then in this case $s = 3$, $l_1 = l_3 = nl$, $l_2 = l$ and $r = 1$, hence $c_1 = d_1 = 0$, $c_2 = d_2$

$=1$, $c_3=d_3=-2\,(n+1)$, $c_4=d_4=\dfrac{3+8\,n+3\,n^2}{n}=\dfrac{H}{n}$, if we put $H=3+8\,n+3\,n^2$. Then $M_1=0$, since for $m=1$, $c_m=c_1=0$. For $m=2$ or $m>r$ we have $M_2=d_3\dfrac{A\,c_1+B\,c_2}{l\,c_2+2(n\,l+l)\,c_3}=-2\,(n+1)$ $\dfrac{B}{l+2\,(n\,l+l)\,(-2\,n-2)}=-2\,(n+1)\,\dfrac{P\,n^2\,l^2\,(k-k^3)}{-l\,(3+8^n+4\,n^2}=$ $\dfrac{2\,P\,n^2\,l\,(n+1)\,(k-k^3)}{H}$. Now for the reaction at left end we have $S_r=S_1=S_A=\dfrac{M_r-M_{r+1}}{n\,l}+q=\dfrac{M_1-M_2}{n\,l}+P\,(1-k)=\dfrac{-M_2}{n\,l}+P$ $(1-k)$ or $S_A=\dfrac{-2\,P\,n\,(n+1)\,(k-k^3)}{H}+P\,(1-k)=\dfrac{P}{H}$ $[H-(H-2\,n-2\,n^2)\,k+(2\,n+2n^2)\,k^3]$ just as already given in Article 4. In the same way we might find the other reaction there given. If we make $n=1$, we have all the spans equal, and if we should insert in place of A and B in the values for M, the proper values for uniform load, we should have the reactions for full load over any span. Making this change in the preceding examples we can compare our results with those given by *Stoney* (Theory of Strains), for the same two cases, and thus prove the accuracy of our formulæ, by a comparison of the results obtained from them, with the results of independent investigations. Such a comparison will also give an idea of the amount of labor and investigation saved by our formulæ. By the ordinary methods, the deduction of the above values would be tedious in the extreme, and would even "task the powers of the best mathematicians."

3. *In a girder of seven equal spans, we have a weight P at a distance a from the fourth support. What is the moment and shear at this support?* (The reader should in every case draw a figure.)

Here $s=7$, $r=4$, and since all the spans are equal $c_1=d_1=0$, $c_2=d_2=1$, $c_3=d_3=-4$, $c_4=d_4=15$, $c_5=d_5=-56$, $c_6=d_6=209$, $c_7=d_7=-780$, etc. Hence $M_r=M_4=c_4\,\dfrac{A\,d_5+B\,d_4}{l\,d_6+4\,l\,d_7}=15$ $\dfrac{-56\,A+15\,B}{209\,l-3120\,l}$, or $M_4=15\,\dfrac{-56\,A+15\,B}{-2911\,l}$. Inserting the values of A and B for concentrated load, we have $M_4=\dfrac{15\,P\,l}{2911}$ $(97\;k-168\,k^2+71\,k^3)$. If in this we give to k its several values for the

various weights, P_1, P_2, etc., and insert the values of P and l, we shall find the values of M_4 for "interior loading," as already given in Article 3. In a similar manner we can find M_5, thus, $M_5 = d_4 \frac{A\,c_4 + B\,c_5}{l\,c_6 + 4\,l\,c_7} = 15 \frac{15\,A - 56\,B}{-2911\,l} = \frac{15\,P\,l}{2911}\,(26\,k + 45\,k^2 - 71\,k^3,)$ knowing now M_4 and M_5, we can find the shear $S_4 = S_r = \frac{M_4 - M_5}{l} + P\,(1 - k)$. If for the same girder, we suppose the first span loaded with uniform load over the whole length, and wish the moment at fourth support, we have $r = 1$ and $A = B = \frac{1}{4}\,w\,l^3$; s, c, and d the same as before, hence for $m = 4$ $M_4 = d_5 \frac{A\,c_1 + B\,c_2}{l\,c_6 + 4\,l\,c_7} = -56 \frac{B}{-2911\,l} = \frac{56}{2911}\,\frac{1}{4}\,w\,l^2 = \frac{14}{2911}\,w\,l^2$; and $M_5 = d_4 \frac{A\,c_1 + B\,c_2}{l\,c_6 + 4\,l\,c_7} = \frac{15\,B}{-2911\,l} = -\frac{15}{2911}\,\frac{1}{4}\,w\,l^2 = -\frac{15}{11644}\,w\,l^2$. Now we can find the shear just to the right of fourth support, *viz.*, $S_4 = \frac{M_4 - M_5}{l}$. In like manner we can find moment and shear at fourth support for third span loaded, as also at same support for sixth span loaded. The sum of all these positive moments and shears will give us the moment and shear at fourth support for first method of "exterior loading," as given in Article 3. In the same way we can find the same quantities for second method of exterior loading. Thus our formulæ give us easily all the data, which in Article 3, we have assumed as known, and which, as we have seen, are sufficient for complete solution.

In the author's work, "Elements of Graphical Statics," will be found tables which may be easily produced to any extent by simple inspection, giving moments and shear, without even using the formulæ. Such tables are, however, scarcely desirable. The formulæ themselves are easily managed and all sufficient for our purpose.

But our formulæ enable us to solve other problems which without their aid could hardly be attempted even. By making, for instance, $l_1 = 0$ in our formulæ, the girder is *fixed horizontally* at the left end, whatever the number of spans. When $l_8 = 0$, it is fixed at the right end. When l_1 and l_8 are both zero, it is fixed at both ends. The girder of single span fixed horizontally at both ends is given in most text books. Let us check our formulæ by comparison with these results. Thus:

4. *A beam of one span is fixed horizontally at the ends. What are the end moments and reactions for a concentrated load distant a from left end? Also for uniform load over whole span?*

Here we take 3 equal spans, or, $s = 3$, but we make l_1 and l_3 both zero in our formulæ. The left end of the girder is then 2, the right end 3, and $r = 2$, $d_1 = c_1 = 0$, $d_2 = c_2 = 1$, $d_3 = c_3 = -2$. For the left end then we have $M_r = M_2 = c_2 \frac{A\,d_3 + B\,d_2}{l\,d_2 + 2\,l\,d_3} = \frac{-2\,A + B}{l - 4\,l}$ $= \frac{B - 2\,A}{-3\,l}$. Now according as we insert the values for A and B, we shall have concentrated load or uniform load. Thus for concentrated load $A = P\,l^2\,(2\,k - 3\,k^2 + k^3)$ and $B = P\,l^2\,(k - k^3)$, hence $M_2 = P\,l\,(k - 2k^2 + k^3)$. For uniform load $A = B = \frac{1}{4}\,w\,l^3$, hence $M_2 = \frac{1}{12}\,w\,l^2$.

For the right hand support we have $m = 3$ or $m > r$, or $M_3 = d_2\,\frac{A\,c_2 + B\,c_3}{l_2\,c_2 + 2\,l\,c_3} = \frac{A - 2\,B}{l - 4\,l} = \frac{A - 2\,B}{-3\,l}$ or $M_3 = P\,l\,(k^2 - k^3)$ for concentrated load, and $M_3 = \frac{1}{12}\,w\,l^2$ for uniform load.

For load in middle $k = \frac{1}{2}$ and $M_2 = M_3 = \frac{1}{8}\,P\,l$.

We can now find the shears S_2 and S'_3 which in this case are the same as the reactions R_2 and R_3, because there is but one span. Thus, $S_r = S_2 = \frac{M_2 - M_3}{l} + q = \frac{M_2 - M_3}{l} + P\,(1 - k) =$ $P\,(1 - 3\,k^2 + 2\,k^3)$ and $S'_{r+1} = S'_3 = \frac{M_3 - M_2}{l} + q' =$ $\frac{M_3 - M_2}{l} + P\,k = P\,(-2\,k^3 + 3\,k^2)$. For $k = \frac{1}{2}$, both these become $\frac{1}{2}\,P$ as should be, and all these formulæ are precisely the same as those found for this case in all text books, thus proving our general formulæ.

5. *A beam of one span is fixed horizontally at the right end only; what are the reactions and the moments for concentrated and uniform load?*

Here we have two spans, or $s = 2$, but we make $l_2 = 0$, so that $r = 1$, and $c_1 = d_1 = 0$, $c_2 = d_2 = 1$, and $c_3 = d_3 = -2$. Then $M_1 = 0_1$ because $c_1 = 0_1$ and $M_2 = d_2\,\frac{A\,c_1 + B\,c_2}{l_1\,c_1 + 2\,l_1\,c_2} = \frac{B}{2\,l}$. Now

inserting the values for B, we have $M_2 = \frac{Pl}{2}(k - k^3)$ or $M_2 = \frac{1}{8} w\, l^2$.

For the reactions or shears, which in this case are the same, we have $S_1 = S_r = \frac{M_1 - M_2}{l} + q = - \frac{M_2}{l} + P(1-k) = \frac{P}{2}(2 - 3k + k^3)$,

or, $S_1 = \frac{3}{8} w\, l$ and $S'_{r+1} = S'_2 = \frac{M_2}{l} + Pk = \frac{P}{2}(3\,k - {}^3)\,k$, or, $S'_2 = \frac{5}{8} w\, l$.

For $k = \frac{1}{2}$, we have $S_1 = \frac{5}{16} P$ and $S'_2 = \frac{11}{16} P$. These formulæ and results are precisely the same as those given for this case in all text books, where they are deduced by a special discussion of considerable intricacy. It will be observed that by the aid of our general formulæ, one case is no more difficult than another, and questions may be readily solved which would be otherwise almost impossible of solution. Thus,

6. *A beam of three spans of* 25, 50, *and* 40 *feet, respectively, is fixed horizontally at the right end and has a concentrated load of* 10 *tons at* 12 *feet from the third support. What are the moments at the supports?*

Ans. $M_1 = 0$, $M_2 = -8{\cdot}20$, $M_3 = 24{\cdot}62$, $M_4 = 42{\cdot}29$. ft. tons. Find the shears, also moments and shears for uniform load over third span.

7. *A beam of four spans,* $l_1 = 80$, $l_2 = 100$, $l_3 = 50$, $l_4 = 40$ *ft., free at the ends, has a load of* 10 *tons in the second span* 40 *ft. from the left end. What are the moments?*

Ans. $M_1 = 0$, $M_2 = 82{\cdot}01$, $M_3 = 88{\cdot}56$, $M_4 = -24{\cdot}65$, $M_5 = 0$. Find the shears, also the moments and shear for uniform load over second span.

Thus we see that a few short and simple formulæ which may be written on a piece of paper the size of one hand, are all that we need for the complete solution of any case of level supports—whether the spans are all equal or all different in length, whether the girder merely rests upon the end supports or is fastened horizontally at one end or both ends. We have only to remember that a positive moment causes tension in upper flange and compression in lower; inversely for negative moment. Also, that a positive shear acts upwards and a negative shear downwards. Also, that both moment and shear are positive at

the supports of the loaded span and alternate in sign both ways from these supports. This is all we need. We can then by our formulæ find the positive moment and shear at any support for 1st case of exterior loading; negative moment and shear for 2d case; and positive moment and shear for each of the interior apex loads. We can then find the strains for each case and each weight with the same ease as for a simple girder, and in precisely the same way. Finally, by our method of tabulation given in Article 3 we can find the maximum strains, for all positions of moving load as well as for dead load, and this not approximately but with absolute exactness.

VIII. CONCLUDING REMARKS.

If we take a girder of 200 feet span, 20 feet high, 10 panels, double system of triangulation, live load 20 tons per panel, and dead load 10 tons per panel, and calculate its strains, first for single span, second, as one span of two equal continuous spans; third, as the centre span of five spans; and fourth, as fixed horizontally at the ends, we have in the second case a saving in strain of 18 per cent.; in the third, of 27 per cent., and in the fourth of 50 per cent., as compared with the first. Such results are surely indicative of considerable advantage and are worthy of serious attention!

THE DISADVANTAGES OF THE CONTINUOUS GIRDERS ARE:

1st. The fact that some of the flanges undergo strains of opposite character.

This, in wrought iron structures, we venture to think of little importance. No difficulty in this respect is found in the diagonals of the simple Warren girder. The extra work and cost of chords and chord connections necessary to secure the flanges against both compressive and tensile strains, can hardly amount to 18, 30 or even 50 per cent. of the cost of girder.

2d. Difficulty of calculation.

We have, we trust, in what precedes, succeeded in removing this objection. The opinion seems wide spread, that the determination of the strains in the continuous girder is impracticable and involved in mystery. No opinion could well be more unfounded. The accurate and complete calculation for all possible loading, live and dead, is precisely similar to, and offers no more difficulty than the simple girder itself.

3d. The changes of strain, unforeseen and often considerable, which a small settling of the piers, or change of level of the supports may occasion.

This objection is only of importance when the piers settle, *after* the erection of the superstructure. If piers are to be considered as settling indefinitely, continuous girders are indeed impracticable. If, however, the piers take in time a permanent set, and afterwards remain immovable, the above objection has no weight. It is not necessary that the piers should be on level, or even on line, or even that the difference of level be known. The proper reactions may, as suggested by Mr. Herschel, be *weighed* off, and the girder thus left in position under precisely the circumstances for which it has been calculated.

THE PRINCIPAL ADVANTAGES OF THE CONTINUOUS GIRDERS ARE:

1st. Ease of erection, where false works are difficult or expensive. The girder may be built on shore, and then pushed out over the piers.

2d. Saving in width of piers, as compared with width required for separate successive spans. The girder may be put upon *knife edges* at the piers. In fact such a construction is desirable as better ensuring the calculated strains. Width of piers is undesirable.

3d. Saving in material, ranging in general from 25 to 30 per cent.

Finally—we do not wish to be understood as claiming that the continuous girder is *in all cases* superior to the simple. It has of course its own place. Theory shows a considerable gain, and in the case of a number of long spans where the piers are solid and false works difficult, the advantages of the continuous girder seem certainly worthy of earnest consideration. The theory upon which our results are based is universally accepted as a good working theory and one whose results are practically correct. Those who seem inclined to find fault with the theory itself would do better service by giving us one more correct, rather than by dissuading others from attempting to obtain in practice the gain indicated by such theory as we have. As is seen from the above, the accuracy of our strains depends *wholly* on the accuracy with which the shears and end moments are given by the formulæ, a few *actual experiments*, made to test the practical accuracy of these formulæ would be more satisfactory and more to the point than any amount of general discussion of the theory of flexure. Such experiments can very easily be made. Those who

consult the author's work upon the "Elements of Graphical Statics" for the demonstration of the above formulæ will find that the *actual amount* of deflection, or whether this deflection can be accurately calculated, has nothing whatever to do with our formulæ. It is with relative deflection only, that we have to do. It has been our object, assuming with the great majority of engineers, the accuracy of the theory of flexure, to show an easy and practical method of calculation, which shall meet one of the main objections to the continuous girder, and to exhibit the gain indicated by theory. This we claim to have done, and in doing it we have given general formulæ, easy of application, which, we may be allowed to think, mark a new and great advance in the mathematical discussion, at least of the subject. Objections of more or less weight can always be urged against any novel construction, especially before such construction has been attempted. Just *how much* weight such objection may have, whether really insuperable or only of service in pointing out to the engineer special difficulties to be met and overcome by special skill, can only be determined by ACTUAL TRIAL. No man without such actual experience can authoritatively state just how much or how little of the theoretical gain can be attained in practice, though there are not wanting those who assume to be equal to the task. The only fair and legitimate way of testing theoretical results seems to be by actual trial. Such at least seems to be the view held abroad. In almost every civilized nation, *except America*, the continuous girder has been or will be put to a practical test, and it is hard to see why it should not be tested here. Those who decide the case *prima facie*, and, in the light of what is doing abroad, dissuade even from experiments, would seem to place rather too much confidence in their own judgment and too little in the skill and enterprise of their compeers in other countries, while their claims as *progressive* engineers are liable to be questioned.

Errata.—In article on Gas Works Engineering, page 35, vol. CII, correct line 22, for two, read ten; line 25, for When a, read Whence. —The computation of the number of feet of air needed for a burner of $4\frac{1}{2}$ cubic feet per hour $=$ 90 cubic feet, is correct.

DAVEY'S DIFFERENTIAL VALVE GEARING.

Abstracted from Thesis of

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One of the greatest defects of the direct pumping steam engine—that is, the pumping engine which is constructed without a crank, and fly-wheel, and a rotary movement, to limit the length of stroke—is its liability to overrun the proper stroke of the piston, to the serious injury of the head, or of the cylinder, or in fact of the whole machine.

In these engines the initiatory motion is imparted to the valve gearing by some tappit or release of catch, as the piston approaches either end of the stroke, while with the intervention of some one of many contrivances, the actual opening of steam ports is deferred until after the whole, or nearly the whole length of the previous stroke of the pump will have been completed. In some way, at the proper time, the valve gearing opens the ports to the steam cylinder, and at some proper and fixed point in the stroke these ports are closed against further admission of steam by another tappit, release-catch, or in some cases a gradual inclined plane movement; so as to allow a maximum of expansion in bringing the piston to rest at the full end of the stroke without shock. With a constancy of load and of steam pressure, this arrangement works satisfactorily, but with the variation of either, and especially of the former—which is most liable to sudden variations, accidental or otherwise—stoppages or overrunning are likely to occur. In the case of the bursting of a main delivery pipe, for instance, the full force of the expansion of the steam which may have (and for a non-compound cylinder steam pump, must have), followed the piston, seven-eighths of the stroke, will be expended in bursting out the cylinder head.

The Cornish engine itself is included in the same category as to danger of overrunning its stroke at either end, in event of disturbance of its motive pressure or working load. In this engine, the steam imparts to an immense mass, a certain momentum in the beginning of the stroke, and aids in the continuance of the motion of the mass until the very end of the stroke is reached, when the elevated mass

comes to rest. The mass on its return descent, imparts to a column of water its proper movement under nearly uniform resistance. Now if accidentally, either the connection between the engine and the ascending mass, or load is broken ; or any material change occurs in the water column resistance, the probability of disaster is very great. Cornish engines require constant attendance to guard against such accidents, but the utmost care fails to prevent these at times. Many of the Cornish engines in this country have suffered injury in this way, of greater or less amount. The instance of a failure at Jersey City two or three years since, may be quoted, where the ensuing expenditures for repairs reached the sum of $25,000.

Within the past two or three years Mr. Henry Davey, of Leeds, England, has introduced a differential (as he denominates it) valve gearing, whereby the valve movement is made to depend upon an independent cataract on the one hand and upon the relative speed of the piston itself on the other.

The cataract, here referred to, is a cylinder with its piston ; which cylinder is full of water on both sides of the piston, and the piston in the course of its movement is made to displace the water from one end to the other end of the cylinder—from one side to the other side of the piston—through a *restricted* side pipe or passage. The motion is imparted to the piston of the cataract by an independent steam cylinder (*J*) *whose valve motion* is derived from a tappit which operates near the end of the stroke of the main steam cylinder ; and the *time* and *uniform resistance* of the cataract follows from the restriction of the side pipe by a screw valve or an equivalent means for controlling the flow of water in the water cylinder. Having thus secured a motion of desired uniformity of rate to be accomplished as a *stroke* in a desired interval of time—say any number of strokes (3 to 60 as wished) per minute—this motion is applied, under Mr. Davey's invention, to operate *indirectly* the steam valve of the engine. This indirect operation is produced by *connecting* the piston rod of the cataract to one end of a balance bar, while the other end of the balance bar is *connected* in the opposite direction to the piston rod of the main engine. The *connection* in the latter case being so planned by rocker arms or inclined slides, that the length of the stroke to that end of the balance bar is in reasonable proportion, or equal to that of the cataract. When it results, that if the main valve rod is joined to the balance bar at some place in its length, the action of the cataract tending to open

the main valve, will be counteracted by that of the engine tending to close it, and the valve will have the "differential" motion.

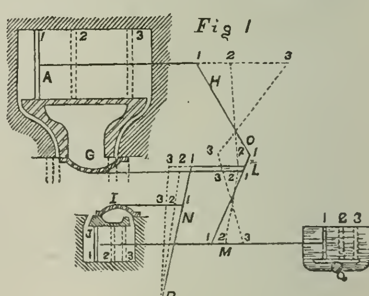
Suppose the engine to have come to rest at one end of the stroke, and suppose a slide valve to be used as the means for admission; of course the valve in such case will have a middle position, and cover the ports of admission at both ends. Just before the engine reached this position of rest, a tappit is supposed to have admitted steam to the cataract steam cylinder, and presently that end of the balance bar begins to move, whilst, as the engine is at rest, the other end of the balance bar is at rest also; and under these circumstances, the point of attachment of the main valve rod to the balance bar is put in motion, and the valve begins to open. The main valve continues to open in this way until the pressure of steam admitted to the cylinder overcomes the resistance of the column of water, when a slow movement commences. The cataract continues on its uniform speed, but as the previous fulcrum end of the balance bar is now in motion, the main valve now opens more slowly. Presently the rate of motion of the two ends becomes coincident, or has such relative speed, that the point of attachment of the main valve rod ceases, when the valve opens no further; or else the cataract, reaching its limit of motion, and will have produced its utmost effect on the valve, when it follows that the engine connection to the balance bar will close up the valve at the end of the stroke; or, on the other hand, the speed of the engine may have been such that its end of the balance bar will have overtaken the cataract end, and shut off the valve faster than the cataract could open it; or, finally, the speed of the engine, in case of a runaway by failure of resistance to pumping, may cause its end of the balance bar to so far overrun the speed of the cataract end as to admit steam on the back side of the piston, and present a steam resistance against the impending contact.

In Mr. Kilham's thesis the following figures are employed to illustrate this action, and his description will complete the elucidation of the apparatus, which is provokingly simple in construction and exceedingly difficult to render intelligible without a working model.

"Suppose, in Fig. 1, the piston A to remain motionless; then the piston J of the subsidiary cylinder, moving at a uniform speed, would move the point L which regulates the valve motion toward the right, thus opening the valve. If then the subsidiary piston J should remain still, and the piston A should move

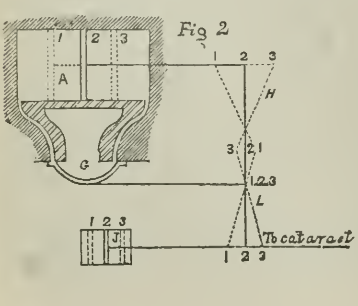
forward, the point L would move toward the left, thus closing the valve; so that if the motions occurred successively, the first would open and the second close the valve, and close it always at the same fraction of the engines stroke, whatever the boiler pressure and load. But if these motions act together we obtain a differential motion compounded of the two. First the steam is admitted to the subsidiary cylinder, and the piston J by its motion moves the rod L and, since steam has not yet been admitted to the main cylinder, L turns about O as a fulcrum, thus opening the valve G. As soon as steam is admitted A begins its motion, slowly at first but more quickly as the inertia of the load is overcome. When A starts there are two tendencies; first that of J to open the valve, and second that of A to close it. At first the motion of L derived from J is the greater, and the valve continues to open, but as the speed of A increases, the motion of L derived from it becomes equal to that derived from J, and the valve motion ceases. As the speed of A still increases the valve begins to close. When the valve is closed, as the steam is working by expansion only, the speed derived from J again becomes equal to that derived from A, the valve again stops at the other end of its throw, and the engine is ready for the return stroke."

Fig 1



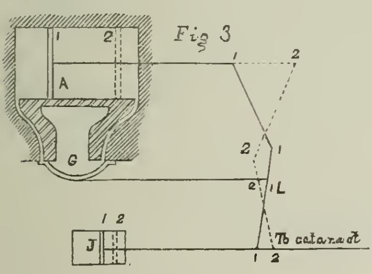
"In Fig. 1. are shown the positions of the different parts of the gear at the beginning and end of the stroke, and at the point of cut-off. In Fig.2, suppose the positions marked 2 to be the positions occupied by the different parts shown in the figure at the point of cut-off, working under the ordinary load. If the load were heavier, the steam pressure being the same, it would take longer for the motion of the valve, caused by the main piston, to equalize that caused by the subsidiary piston, and it would therefore be longer before the direction of motion of the valve would be changed, and longer before cut-off would take place than with the ordi-

Fig 2



nary load. If on the other hand the opposite should occur, the cut-off would take place earlier in the stroke. The positions marked 3 and 1 are those occupied with a heavier or lighter load."

"If from any cause the load was suddenly thrown off the increasing speed of the piston would be immediately felt by the valve, which would thus be changed to compensate for the loss of load. First suppose that the load is thrown off before cut-off occurs, then the increasing speed of the main piston quickens the cut-off. Second, suppose the load continues as ordinarily until just after steam is cut off, and then the load is thrown off—the subsidiary piston *J* will move on uniformly, unaffected by the load, while the main piston, having little resistance, moves with great velocity, so that the subsidiary piston moves a very short distance compared with the main piston. Actuated by the main piston principally, the valve moves quickly and opens before the valve reaches the end of its stroke. The positions at point of cut off and near the end of the stroke are seen in Fig. 3. By the admission of steam the piston is stopped, and would begin to move the other way, but since both its motion and that of the subsidiary piston tend now to close the valve, no more steam will be admitted until the subsidiary piston reaches the position ordinarily occupied at admission."



The description and sketches given above, do not exhibit the constructive details and mechanism of Mr. Davey in actual use. A paper read by him before the Institution of Mechanical Engineers in 1874, shows many examples, both of proposed and accomplished application. This paper, with further additions, has been subsequently republished in various engineering journals. It has been here attempted, to present as clearly as possible, the principle of controlling movement involved in Mr. Davey's plan, divesting the mind of the reader from the embarrassment of consideration of methods of construction. The refinements for adjusting tappits, whereby the cataract steam (or motive) cylinder is operated, and the control or regulation of their action, have been fully comprehended and met by Mr. Davey, as will be found by any person, who shall pursue the inquiry into

his published articles. The valve gearing itself is an adaptation of what has been applied to meet similar requirements in mechanical combinations repeatedly, so that no part can be called novel or entirely original. Perhaps the nearest approach to the same application is that used in the movement of valves for the Davy (Davy of Sheffield, not Davey of Leeds), steam hammer, which has now met with nearly universal acceptance for the hand and power valve movement for steam hammers. But the combination of the governing cataract with the balance bar, for operating the valves of steam pumping engines is (the writer thinks) new, and is probably the most important modification of this valve gearing effected since the time of Smeaton, that is, within the last century of the history of pumping engines.

VENTILATION.

An abstract from a paper by Gabriel James Morrison, M. Inst. C.E., was read before the

INSTITUTION OF CIVIL ENGINEERS,

London, January 18th, 1876, on the subject of the Ventilation and Working of Railway Tunnels. The reading was followed by a discussion which was participated in by many of the most eminent engineers of England, and the results of experience and study were elicited in exceedingly instructive forms. The great end of the paper and discussion was to consider the means of ventilation requisite for the proposed "Channel tunnel" of 22 miles in length; and those readers, who wish to investigate or understand the methods for effecting the purpose suggested or advocated by the different engineers, are referred to the proceedings of the Institution for the complete report. But there were several data given in the paper, and by different speakers, which possess more general interest, which can be appropriately abstracted in the JOURNAL.

For instance, Mr. Morrison gives a succinct statement as to FRESH AIR, ITS COMPOSITION AND PROPERTIES, which can be quoted.

"Pure air consists, approximately, of 23 per cent. of oxygen and 77 per cent. of nitrogen, weight for weight—or 21 per cent. of oxygen and 79 per cent. of nitrogen, comparative volumes:—but in addition, the atmosphere always contains carbonic acid, so constantly, that it is questioned whether this gas be not a necessary constituent. The quantity is very small, for Dr. Angus Smith states that on the

hills in Scotland the proportion was found to be 3·3 per 10,000; in the open parts of London 3 per 10,000, and in London streets 3·8 per 10,000.* In this paper fresh air will be considered to contain $3\frac{1}{2}$ parts of carbonic acid in 10,000 parts; and the temperature of 60° Fahr. will be generally adopted, at which temperature the weight of a cubic foot of air is 0·0765 lb.

The specific gravity of air being . .	1
That of oxygen is	1·1
" nitrogen	0·97
" carbonic acid . . .	1·52

"Carbonic acid consists of 6 parts by weight of carbon and 16 parts by weight of oxygen: the volume of the Carbonic acid is the same as that of the sixteen parts of oxygen. This gas is therefore $\frac{6}{16}$ heavier than oxygen."

In another place in his paper Mr. Morrison gives the following empirical formulæ for the Flow of Air through Ducts or Passages.

"The friction of air varies as the square of the velocity multiplied by the pressure against the sides of the passage. This pressure being uniform, its total amount depends upon the total surface, that is, the length multiplied by the perimeter of the cross section. The force required to propel air through any passage is therefore equal to the square of the velocity into the total surface multiplied by the coefficient of friction. It is more convenient to state the force in lbs. per square inch or per square foot, or as so many inches of water pressure; the above result should therefore be divided by the area of the cross section.

The best form of the formula for practical purposes of ventilation seems to be: $H = \frac{K V^2 P L}{A}$, where

H = head of pressure in feet of air of same density as the flowing air.

L = length of the pipe or passage in feet.

P = perimeter of cross section in feet.

A = area of pipe or passage in square feet.

V = velocity in thousands of feet per minute.

K = co-efficient of friction = 0·03.

This formula is perfectly general, and may be used for any fluid; H will always be the head stated in feet of the flowing fluid.

* "Air and Rain." By Robert Angus Smith. 8vo., London, 1872.

The weight of 1 foot of air, at 60° Fahr., is 0·0765 lb. per square foot. The weight of 1 inch of water is 5·2 lbs. per square foot. Therefore if it be desired to reduce any result in feet of air to its equivalent in inches of water, the process is simply to divide it by $\frac{5·2}{0·0765} = 68$.

For circular passages, taking D for the diameter, the formula becomes $H = K\ V^2 \times \frac{4\ L}{D}$.

These formulæ are only applicable to passages whose diameter is small in proportion to their length. For short passages the length should be increased by about 50 diameters of the passage: thus the formula for circular passages becomes $H = K\ V^2 \times \frac{4\ (L + 50\ D)}{D}$, and that for irregular-shaped passages, $H = K\ V^2 \times \frac{P\ L + 200\ A}{A}$.

The value 0·03 is deduced from a formula explained by Mr. Hawksley, Past-President, in a discussion on the ventilation of Coal Mines.*

In a paper on the Ventilation of Coal Mines, read before the Geological Society of Manchester in 1862, Mr. Atkinson adopts the same formula as the author, but gives a constant of 0·26881, or nearly ten times that of most authorities.† Mr. Atkinson gives a table of co-efficients depending on the material of which the passage is composed:—

Material.	Observer.	Co-efficient.
Burnt earth . . .	Peclet	0·268
Galleries of coal mines .	Greenwell	0·254
Sheet iron (clean) . .	Peclet	0·067 to 0·105
Cast iron (old and tarred)	Giraud	0·048
Gas in pipes . . .	Hawksley	0·030
Water in pipes . .	Eytelwein	0·030
Sheet iron (old and rusty)	Girard	0·027
Tinned iron . . .	D'Aubuisson	0·025

In a discussion on Fans, Mr. Greenwell stated that the co-efficient of friction varied according to the nature of the sides of the passage,

* *Vide* Minutes of proceedings Inst. C. E., vol. vi, p. 192.

† Quoted also, by C. Cope Pearce, in the transactions of the South Wales Institute of Mining Engineers, vol. v. The figures, however, are taken from the original.

as shown by Girard, D'Aubuisson, &c.* To this Mr. Hawksley replied that these discrepancies arose from badly conducted experiments; he had had good opportunities of making experiments in mines with long uniform airways, as well in pipes, and there were not in reality any such differences of co-efficients. On another occasion† Mr. Hawksley said that, when the density of any elastic fluid did not materially vary throughout the length of the pipe, the same rule as for inelastic fluids applied, and that the general formula was $V = 48\sqrt{\frac{h\,d}{l}}$. V being the velocity in feet per second; this formula, reduced to the form adopted by the author, gives a constant of 0·031. From Eytelwein's formula according to Beardmore the author deduces 0·028 as the constant. In a paper by Mr. Lowe, the constant is given as 0·030, and in an old formula, possessed by the author for many years, the constant is given as 0·028. From experiments on the pneumatic tube from Euston to Holborn,‡ taking the velocity of the air to be that of the carriage, allowing nothing for the work done in moving the carriage, a maximum value is obtained of 0·036, and making allowance for the weight of the carriage, the results give a probable value for the constant of 0·027. The experiments in Lime Street tunnel (at Liverpool), are not well suited for deducing a constant,|| the length, 1,200 yards, being hardly as great in proportion to width as is desirable. From the data given, making use of the formula for short passages, the constant comes out 0·049; but the velocity of the air may have been higher than taken: a difference of 20 per cent. would bring the constant to the same figure as the others. From experiments made at Crewe, shortly before the ventilation of this tunnel was carried out, the following formula was deduced:—

Discharge in cubic feet per hour, $1{,}314\sqrt{\frac{d^5\,h}{l}}$; $d =$ diameter of pipe in inches, $h =$ head in inches of water, $l =$ length in yards. This gives a constant for the formula adopted by the author, of 0·029. The author believes that the authorities quoted are sufficient to justify him in adopting 0·03 as the value of the constant K.

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* *Vide* Minutes of proceedings Inst. C. E., vol. xxx, p. 304.

† *Ibid.*, vol. xxxiii, p. 53.

‡ "Engineering," 23d Aug., 1872.

|| *Vide* Inst. Mech. Eng., proceedings, 1871, p. 22 *et seq.*

It will be convenient now to consider the best position for applying the power, so as to insure the supply of a proper amount of fresh air.

The most obvious arrangement is to withdraw the air from the centre of the tunnel. Where this method is applicable no other can compete with it; no valves or doors are required; the air enters at both ends of the tunnel; and the speed of current necessary for ventilation is therefore only half what it would be if the current entered at one end and passed out at the other.

This system has been adopted at Lime Street tunnel, Liverpool. The tunnel is 2,025 yards long, and the air in it is entirely changed in eight minutes; 431,000 cubic feet are withdrawn per minute, and the resistance of the tunnel is so slight that a partial vacuum of 0·14 inch of water is sufficient to cause this; indeed almost the whole of the power appears to be expended in overcoming the friction of the air in the shaft. The case is somewhat peculiar. There is a considerable incline, and therefore the heavy (that is to say, the coal-burning) traffic is in one direction only. The fan is placed in a shaft 1,212 yards from the lower end of the tunnel. As soon as a train is ready to start, the fan is set in motion. The train takes three minutes to run through; the lower portion of the tunnel is entirely cleared in five minutes, and the upper portion in four and a half minutes from the time the train reaches the top of the tunnel. The fan is only worked when required: when not at work the tunnel clears itself by natural ventilation in forty-five minutes. In the case of short tunnels, with frequent trains, or of long tunnels with a smaller number of trains, this intermittent system would be inapplicable.

A tunnel half a mile long, with thirty trains per hour, would represent the worst cases on the Metropolitan railway. If artificial ventilation were adopted, all the products of combustion must enter the tunnel. At a shaft near the centre of the tunnel, all the air might be drawn from the stations, which would then be constantly full of fresh air, and the passengers on the platforms would never feel any discomfort. Supposing, as in the second example given above, a consumption of 24 lbs. of carbon per train mile, to bring the amount of carbonic acid down to the proportion of $8\frac{1}{2}$ parts per 10,000, the tunnel must be filled three times for every five trains, or eighteen times per hour; as the tunnel is a half mile long, and is filled from both ends, the velocity of the current will be nearly 400 feet per

minute, and there must be withdrawn $473 \times 400 \times 2 = 378{,}400$ cubic feet per minute. This is less than the duty of the fan at the Lime Street tunnel.

The head of pressure is: $H = K V^2 \times \frac{P L + 200 A}{A} = 0{\cdot}03 \times 0{\cdot}4^2$ $\times \frac{83 \times 1{,}320 + 200 \times 473}{473} = 2{\cdot}07$ feet of air $= 0{\cdot}03$ inch of water.

As probably a head of $\frac{3}{4}$ inch of water, or 3·9 lbs. per square foot, will be required to force the air through the passages leading from the tunnel, the friction of the tunnel proper is not worth considering. Air to the amount of 380,000 cubic feet per minute withdrawn against a vacuum of $\frac{3}{4}$ inch of water represents an effective *HP* of

$$\frac{380{,}000 \times 3{\cdot}9}{33{,}000} = 45.$$

At such low pressures, the effective power of a fan can scarcely exceed 50 per cent. of the indicated *HP* of the engine, so that about 90 *HP* will be required.

A tunnel 7 miles long, with sixteen trains per day, consuming on the average 35 lbs. of carbon per mile, would have to be filled once for each train, or sixteen times in twenty-four hours. This would require a current from one end to the other of 410 feet per minute; for, in the case of very long tunnels, it rarely happens that it is possible to have a shaft in the middle. In the Hoosac Tunnel there is such a shaft, and of course if that tunnel were to be ventilated artificially, advantage would be taken of it; but, as a rule, long tunnels are constructed to overcome great natural obstacles, and are without a shaft from end to end.

Assuming the same size of tunnel as before, and taking the formula for long passages, $H = \frac{K V^2 P L}{A} = \frac{0{\cdot}03 \times 0{\cdot}41^2 \times 83 \times 36{,}960}{473}$, $= 33$ feet of air $= \frac{1}{2}$ inch of water. If $\frac{3}{4}$ inch be allowed for the friction in the air channels, it will give $1\frac{1}{4}$ inch pressure altogether. The necessary pressure in mines is often considerably higher; but even in what are considered properly ventilated mines, the air-passages are often so small that a man can scarcely crawl through them. If the number of trains be twelve per day, the average current to ventilate the tunnel will only be $3\frac{1}{2}$ miles per hour; and if a proportion of $13\frac{1}{2}$ parts of carbonic acid per 10,000 be permitted, it will only be $1\frac{3}{4}$ mile per hour."

Doct. Letheby (since deceased) gives some very valuable statements on "THE QUANTITY OF CARBONIC ACID EVOLVED IN RESPIRATION, ETC."

"Experiments dating from the time of Sir Humphry Davy had established beyond question the precise quantity of carbonic acid produced by each individual when at rest. Each person consumed about $2\frac{1}{4}$ grains of carbon per minute, equal to 8·25 grains, or rather more than 17 cubic inches, of carbonic acid, and, with the hydrogen consumed in his body, it amounted to about 20 cubic inches of atmospheric oxygen consumed in a minute. Dividing the 7,000 grains making a pound of the combustible, by $4\frac{1}{2}$ grains, the amount consumed by each person in the run of 1 mile at the speed of 30 miles an hour, it would be seen that there were one thousand five hundred and fifty persons to every pound of carbon. That was an important consideration in regard to the extent to which each individual vitiated the atmosphere, for it showed that the vitiating effect of respiration was insignificant. With reference to other vitiating agents, carbonic oxide was one of the most deadly. One per cent. of it in the atmosphere of a tunnel would kill every person in it in ten minutes: hence the great importance of a perfect combustion of carbon. As to carbonic acid, the proportion found in the breath was about $4\frac{1}{2}$ per cent., but this was irrespirable; even 2 per cent. of carbonic acid in the atmosphere was exceedingly distressing. In some dormitories examined by Dr. Bence Jones, where the "casuals" were in a very uncomfortable state, the percentage of carbonic acid was only $1\frac{1}{4}$. In others in England and France, where there were from 58 to 80 volumes of carbonic acid in 100,000 of air, the inmates did not appear to suffer much; and the same was the case with some of the crowded lodging-houses of the city, where he had found as much as 100 volumes in 10,000 of air: so also in certain mills and workshops with from 28 to 30 volumes of carbonic acid in 10,000 of air. The atmosphere of the Court of Chancery had contained 19·8 volumes of carbonic acid in 10,000; that of the Chamber of Deputies in Paris, 25 in 10,000; the London theatres, 10·2 in 10,000; and those of Paris from 23 to 43 per 10,000. He thought therefore that the maximum of carbonic acid of 15 volumes to 10,000 volumes of air could be endured for a time in a tunnel. Not that he would recommend any one to live constantly in such an atmosphere, but he did not know that it would do any harm for a reasonable time. He

looked upon 10 in 10,000 as the point where the atmosphere was getting bad; but there were many instances in which persons lived, apparently without discomfort, in an atmosphere containing considerably more than 15 volumes of carbonic acid in 10,000 of air. There was, he thought, no great cause for alarm with regard to the future of tunnels: for supposing that a normal atmosphere contained 4 volumes of carbonic acid in 10,000 of air, and that 15 volumes of carbonic acid might be permitted to exist in it, then if 35 lbs. of pure carbon were consumed per mile in a tunnel there would be produced 1,097 cubic feet of carbonic acid gas, which, with the oxygen consumed, would require only 1,002,757 cubic feet; amounting, with a sectional area of 473 square feet, to 2,120 feet of tunnel, or about $\frac{4}{10}$ mile. So that supposing the tunnel to be impervious, not allowing the diffusion of gases through the walls, if it were ventilated once for every two trains, that would be a good and effective ventilation. But suppose the ventilation could not be effected, the question will then arise whether some other fuel, less vitiating in its action, could not be used. Twenty-seven pounds of benzole, doing the work of 35 lbs. of pure carbon, or of 37·9 lbs. of coke containing 92·4 per cent. of carbon, would consume 980 cubic feet of oxygen, and produce 786 feet of carbonic acid, and it would vitiate only 719,445 feet of air; 27·7 lbs. of the common oils, doing the same work, would consume 1,072 cubic feet of oxygen, and produce 673 cubic feet of carbonic acid, vitiating 617,178 cubic feet of air. The fuel that vitiated the atmosphere to the least extent was wood spirit; but it was unfortunate that, in descending in the scale of vitiation, compounds were reached that were richer and richer in hydrogen, and therefore more and more volatile, though they might be used in the form of spray from a jet. In the case of paraffine oil, it took 23 lbs. to do the work of 25 lbs. of pure carbon, the oil consuming only 932 cubic feet of oxygen, producing 621 cubic feet of carbonic acid, and vitiating 569,202 cubic feet of air. But was it possible, by any contrivance, to use hydrogen? No carbonic acid would then be generated; there would simply be an abstraction of oxygen. He had made experiments on birds, to ascertain how far he could go in the absorption of the oxygen of the atmosphere, taking care to remove the carbonic acid as fast as it was produced; and he found that he could bring down the proportion of oxygen to less than one-half without the bird showing any sign of distress. Now 11·6 lbs. of hydrogen would do the work of 35 lbs. of pure carbon. It amounted

to nearly 2,190 cubic feet; and if that could be carried, it would consume only 1,095 cubic feet of oxygen, producing no carbonic acid, and it would only destroy 5,460 cubic feet of air. The hydrogen might be so used that the whole theoretical quantity of heat (twice as much as the practical quantity) might be utilized; and, considering how much was lost by the carbon, he was not sure whether $5\frac{1}{2}$ lbs. of hydrogen, instead of over 11 lbs., would not do the work of the 35 lbs. of carbon. Then another question arose, whether, if the fuel could not be altered, anything could be used to absorb the carbonic acid as fast as it was produced? Twenty-eight pounds of lime would absorb 22 lbs of carbonic acid, the product of 6 lbs. of carbon. He did not think there would be much practical difficulty in the use of lime in a tunnel, if, instead of the engine discharging the steam and the products of combustion together, the products of combustion were made to pass through lime purifiers; and in that way the whole of the carbonic acid would be absorbed.

Mr. Tomlinson (whose previous popular publication has made him an authority in ventilation) describes the first results of the efforts, made under his direction, in ventilating the tunnels of the Metropolitan railway. Frequent shafts already existed along the lines of tunnels of this railway, which had been constructed with a view to give outlet or escape to the foul air, previous to a last attempt to relieve the difficulty, and these shafts have been made effective by the interposition of some deflecting screens, placed within the tunnel, across the headroom, above the top of the trains. By means of these deflectors the current of air which flows with any passing train is intercepted, and directed by the form of the screen surface upward and outward, through half of the shaft opening, which is bratticed or partitioned off for the efflux of the foul air; while the vacuity of air, which is created on the opposite side of the screen, after the train had passed, is supplied by fresh air, which is sucked down the other half of the divided shaft, (the inner side of the screen having the proper shape to induce the entering air to follow the train with the least resistance).

For tunnels where one or more shafts are practicable, this method of Mr. Tomlinson appears, with the possibility of many modifications, to present a ready and economic way of obtaining the desired relief. An investigation of the nature of the current of air accompanying a train, either in open air or enclosed in long or short ducts, at different rates of speed, might form a proper sequel to these "proceedings"

of the Institute. Such an enquiry would probably demonstrate, that, at some given length, rate of speed, and number of trains, a short double or single track tunnel of given cross sections would be practically self ventilating; and that the length of a single track tunnel which should not demand or make desirable some other means of ventilation would far exceed that of a double track; so that at some point a double tunnel should be preferred to a single one for a double track line, etc., etc.

It is apparent that this method of Mr. Tomlinson is not applicable to tunnels of great length, where frequent shafts, as compared to the traffic, are not admissible, as for instance the Mt. St. Gothard, Mt. Cenis, or the Channel tunnel; and that further and more complete information in accordance with the suggestion of Doct. Pole, as to the condition of ventilation at the Mt. Cenis tunnel at this time would be highly acceptable.

Chemistry, Physics, Technology, etc.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS DURING THE LAST TEN YEARS.*

By Dr. A. W. Hofmann.

From the *Chemical News.*

[Continued from Vol. cii, page 57.]

A few singular proposals for effecting a reduction of temperature may be finally mentioned. J. B. Toselli, of Paris,† causes a spiral pipe to revolve in a vessel of water, from which it simultaneously, during each rotation, raises a certain quantity of water and transfers it to an adjacent vessel, whence it flows back through a worm into the former. The spiral, during its revolutions, has its entire surface moistened. A ventilator drives air against it, evaporates the adhering layer of moisture, and thus lowers the temperature of the tube and of the water it contains. A refrigeration of from 2·7° to 18·3° C. is

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* "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

† Toselli, *Mech. Mag.*, 1872, 433. *Dingl. Pol. Journn.*, ccv, 28.

said to be thus produced according to the weather. In the second vessel, which is traversed by a worm containing the cold water, is placed the liquid to be cooled, such as worts of beer, artificial mineral waters, &c. The effect produced can be but trifling, and depends entirely on the state of the weather, and on the amount of atmospheric moisture, which is never wanting. A psychrometer fixed in the place where the experiment is to be made will show the result beforehand with tolerable accuracy.

Ballo,* of Pest, produces cold by forcing very finely divided air through bisulphide of carbon. The condensation of the liquid needful for its recovery is a hindrance, on which, in fact, the entire project must be wrecked. A recovery of the bisulphide of carbon by any other means than by condensation and refrigeration of the air saturated therewith is, in the absence of suitable solvents, impossible. Even by this means it would involve much difficulty and a great expenditure of force, and would bring us back to the principle of the air machine. In this direction the problem is practically incapable of solution.

Preservation of Ice.

As a supplement to our report on the principles of the artificial production of ice, and on the apparatus hitherto devised for this purpose, a few words must be added on the arrangements for the preservation of cold in the concentrated form of ice. This is a question of great practical importance. Ice machines, however they may be eventually improved and their effect increased, will never, in the more northern parts of the temperate zone, where a moderately cold winter with frost is generally experienced, acquire importance enough to meet the demand even approximately. They will serve merely as valuable substitutes to render us independent of the fickleness of the seasons. Even in more southern regions where ice machines are the only source for obtaining ice, they must work to stock and fill magazines, since the demand does not go hand in hand with the production, but varies with the weather. There is in general no conception of the quantities of ice which certain trades require, and which are consumed in domestic life where its use has grown into a necessity. In 1866 the quantity of ice consumed in New York and its vicinity amounted to 250,000 tons (254,015 metric tons) or 5 cwts.

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* Ballo, *Dingl. Pol. Journ.*, ccxi, 345.

per head. The weight stored up was 543,000 tons (551,721 metric tons), whilst the capital employed in the trade amounted to 2,160,000 dollars. The retail price was for quantities of 5 to 12 kilos. 4 pfennige* per kilo., but for quantities of 1 to 10 cwts. only one shilling per cwt.

In 1871 a company in Berlin, the "North German Ice Works," stored up 600,000 cwts. of ice, and delivered it to subscribers at 77 pfennige per cwt. The quantities of ice consumed in brewing may be learned from the following data, which the author obtained in 1869 from Dreher's brewery at Klein Schwechat, near Vienna :—This establishment brewed, in 1867, 483,150 Viennese eimers, = 273,463 hectolitres, and stored up 515,600 cwts. (28,874,219 kilos.) of ice. In the following year these numbers rose to 492,499 eimers (278,754 hectolitres) of beer and 563,058 cwts. (31,531,924 kilos.) of ice. On an average 1 cwt. of ice is used per eimer (56·6 litres). In a prolonged frost of 2 months this quantity can be procured at the cost of 7 Austrian kreutzers (14 pfennige) per cwt. In shorter periods of cold the price rises to from 10 to 12 kreutzers, to which must be added 1 kreutzer for shoveling into the ice cellars. In mild winters the ice is brought in part from Styria; as the cold weather in 1869 set in late, 26,000 cwts. (1,456,031 kilos.) were procured from there, costing, by the time it reached the brewery, 115 florins per 200 cwts.

In breweries ice is still universally stored in walled pits, which are placed near the store cellars, and keep the latter cool. In Dreher's establishment the cellars occupy 113 cubic fathoms = 771·05 cubic metres, serving to store 3600 to 3800 eimer of beer = 2038 to 2151 hectolitres, and the adjoining ice pit contains 65 cubic fathoms (413·52 cubic metres) holding about 6510 cwts. (368·466 kilos.). The ice pits have the defect of being costly in construction and uncertain in their action. If ground water flows in over the floor, the ice melts rapidly. Where ice is stored up for sale in large quantities it is better to construct ice houses above ground, after the American plan, consisting essentially of double walls of wood with an interval of at least 0·3 filled with some bad conductor of heat, such as sawdust, chaff, loose peat, &c., in a dry state. Thus, the North German Ice Works at Berlin had, in 1871, an ice house 180 metres long, 24 wide,

* The German "pfennig" is about the tenth part of an English penny.

and 10 high, for the storage of 600,000 cwts. of ice. Such ice houses are cheaper than the subterranean ice pits, more convenient in use, and preserve the ice better, if only the layer of non-conducting matter is thick enough. The author* has treated this subject at length elsewhere. Every season new methods of preserving ice are announced in the papers. None of these are at all novel in principle; they depend upon causing a heap of ice to freeze together, if possible, and then covering it with a bad conductor of heat, such as straw, moss, &c. This is in the south of Germany but an unsatisfactory method; far in the north, especially in Russia, it may succeed. Such coverings, further, are very perishable. A cheap and effective ice house on a small scale can only be made in our latitude by preparing two cubic boxes, the inner measuring not less than 2 metres with an interval of at least ½ metre between it and the exterior box in every direction. This interval is not left void, but filled with chaff, chopped straw, dry spent tanner's bark. The only entrance is a door of the same thickness as the sides. According to calculation in a well-made ice house of this construction the ice scarcely melts in a year at the distance of 15 centimetres from the walls. To divide the interval between the double sides into several compartments alternately filled with a bad conductor and left empty—as occasionally recommended—is decidely irrational, being more costly and less effective than a single well-filled broad interval. The air, though the worst conductor of heat, yet if it can move freely in a given space, rapidly transfers heat from a warmer to a colder surface. It is sometimes recommended, and even attempted, to improve a bad ice house by throwing a quantity of salt upon the ice. The author has shown† that this is a very irrational procedure, since, although the cold may be increased to the senses, a considerable loss of ice ensues, the access of heat to the ice pit being accelerated by the augmented difference in temperature.

The preservation of ice is not only important on the large scale, but it is of consequence on the small scale in domestic operations. Food is to be kept cold and thus preserved from decay, or ice is to be used directly for cooling purposes. For this purpose closed boxes are employed under the name of ice cupboards or ice chests. The theory of these contrivances has been examined by the author‡. The ice

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* *Baden. Gewerbzeitung.*, 1870,71, iv, Nos. 5 and 6.

† *Baden. Gewerbzeitung.*, 1868,74.

‡ *Baden. Gewerbzeitung.*, 1868, 66, and 1869, 11 and 16.

closets are cupboards with double sides, the interval filled with chaff, &c., and the insides carefully lined with sheet zinc. The interval between the sides is often too small. According to the author's experiments, the entire breadth of the double side should not be less than 10 centimetres if the ice is to be preserved from rapid melting and a temperature of say 4° C. is to be maintained within. It is also preferable to place the ice in the entire upper third of the closet so that the lower two-thirds remain at liberty for food, &c. The entire cover is then made to open. The ice can then be easily taken out in pieces, and the whole lower space is equally cold, whilst if the ice is placed in a lateral compartment, as soon as it melts only the lowest part of the closet is thoroughly cooled.

Chlorine, Bromine, Iodine, and Fluorine.

By Dr. E. MYLIUS, of Ludwigshafen.

The application of the three closely allied halogens, chlorine, bro mine, and iodine in the chemical arts depends entirely on the energy with which they combine with electro-positive elements, more especially with hydrogen. In this respect chlorine enjoys the pre-eminence. Its most extensive application in the free state is, therefore, as a bleaching and disinfecting agent. Its efficacy depends here essentially on its remarkable affinity for hydrogen, which, under certain circumstances, even exceeds that of oxygen. Its more energetic affinities, in comparison with bromine and iodine, render it a convenient agent for obtaining the two latter. In fact the preparation of free bromine and iodine depends mainly on the decomposition of their hydrides by chlorine. A further chemical attribute of chlorine is its tendency to form with most metals soluble compounds. This behavior is the more readily utilized, since hydrochloric acid, which may be regarded as an industrial by-product, affords a very cheap means of obtaining soluble chlorides af almost all the metals. Free chlorine is also employed as a solvent, *e. g.*, for separating and refining the precious metals, with the exception of silver.

Bromine and iodine are valuable to the chemist not so much on account of their energetic affinities as by the feeble power with which they maintain their position when combined with electro-positive elements. This weaker affinity plays a part, as already mentioned, in their production, and is at the same time the foundation of their uses. Photography, in particular, is based upon the instability of

the bromide, iodide (and chloride) of silver; scientific chemistry and tinctorial chemistry utilize it extensively on account of the readiness with which bromides and iodides of the hydrocarbons and of the metals are mutually decomposed.

Of less importance to the chemist is the property of bromine and iodine—like many of the rarer elements—of excercising a perturbing action upon the healthy animal organism. The physician employs them, therefore, chiefly in combination with the alkaline metals, as valuable remedies.

Fluorine holds a distinct position from the remaining halogens, both in scientific chemistry and in technology. It is endowed with such powerful affinities as to be scarcely known in the free state, whence its energies, as a general rule, do not admit of application. Its affinity for silicium is alone utilized, hydrofluoric acid being employed for the decomposition of silicates, etching on glass, &c.

Chlorine and its Compounds.

Hydrochloric Acid.—As the initial point for the entire production of free chlorine and its compounds we still employ hydrochloric acid, which is obtained in the largest quantity as a by-product in the manufacture of alkali on Leblanc's process. The amount of hydrochloric acid liberated in this process is so enormous that if it were entirely converted into the transportable liquid acid the supply would far exceed the consumption, greatly as this has been recently extended. Hence, especially in England, little pains had been taken for the perfect condensation of the acid gas, so that vast quantities escaped into the air, and, becoming dissolved in atmospheric water, returned as rain in the neighborhood of the works and effected manifold damage, giving thus rise to well-founded complaints on the part of the owners of the adjacent land. This rendered in England a law necessary known as the "Alkali Act" prohibiting the escape of more than 5 per cent of the total hydrochloric acid evolved. In consequence the soda manufacturers were compelled to pay increased attention to the condensation of the hydrochloric acid. The arrangements for this purpose have been improved, not only in England, but the question has been zealously taken up in France and Germany. The inducement was, on the one hand, the growing consumption of the acid and its consequent increasing value, and on the other, a wish to anticipate the complaints of the neighboring residents and thus escape a law similar to that of England, the operation of which occasions the

manufacturers decided inconvenience. In future it will be still more necessary to condense the hydrochloric acid due to Leblanc's process, as far as possible, if, as is probable, the manufacture of soda on the "ammonia" process should become more general.

Whilst formerly it was deemed sufficient to make use of the well known *bombonnes* (groups of Woolf's bottles on a large scale) in which the gases escaping from the pan were absorbed, the method of coke-towers has become latterly universal, which enables the diluted gases to be arrested as they escape from the calcining furnace. This is greatly facilitated by the increasing use of muffle-furnaces instead of reverberatories.

The conditions to be observed in order to obtain the most perfect possible condensation of the hydrochloric acid gas, as ascertained by the exhaustive researches of E. Kopp,* G. Lunge,† and A. Smith, are as follows:—

A sufficient cooling of the gases before entering the absorbing apparatus, a sufficient volume of water, the largest possible surface of contact between the water and the gas, and the simplest possible construction of the apparatus for condensation.

The refrigeration of the gases, especially those from the calcination spaces, is most conveniently effected by means of cold air. Cold water is, indeed, employed as a refrigerant in some establishments in Germany and France, but the difficulties involved can only be successfully combatted on the small scale. In larger works cold air is preferable and is universally employed in England. Refrigeration becomes absolutely necessary where reverberatories are used for calcination, and the gases pass at once into the coke-towers. In this case the heat is so considerable that the coke may take fire, a result which has actually happened.

The apparatus employed in English works for cooling the gases consists chiefly of pipes which are either conducted straight onwards with a slight inclination, or where it is desirable to economize space, are arranged descending and ascending in the form of a U. These pipes are made of fire-clay of from 0·4 to 0·6 metre internal diameter, and fit into each other by means of contracted ends. The joints are made good with a mixture of fire-clay and coal-tar. If possible this series of pipes is carried with a fall of 0·05 to 1 metre for 35 to 70

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* E. Kopp, *Moniteur scientifique.* 1866, p. 611.

† G. Lunge, *Dingl. Pol. Journ.*, clxxxviii, 322.

metres to the condensers, which, to obtain the strongest possible acid, may be either Woolf's bottles or, as in many cases preferable, stone troughs. The latter have the great advantage that the many elbows of the connecting pipes, which impede the movement of the gases, may be more easily dispensed with. They are best made of sandstone slabs let into each other and held together with tie rods which pass through the projecting ends of the side slabs. Or the slabs are fitted together with their edges beveled to an angle of 45°, tightened by the interposition of strips of caoutchouc, and the whole clamped together with a somewhat expensive iron frame work. Lunge decidedly recommends the former plan. Troughs cut out of a solid block are sometimes used in Germany, especially in the neighborhood of sand-stone quarries. Such, however, if of large size are very costly, and if once damaged can scarcely be repaired. The sand-stone used in Germany after it has been shaped out requires to be saturated with coal-tar, as it is otherwise unable to resist the action of the acid. Very hard stone, such as the carbonaceous sandstone (Kohlen sandstein) quarried at Herdecke and Wetter, in Westphalia (Hasenclever), does not require this preparation. Many English sandstones are sufficiently compact to resist the muriatic acid without any preparation (see the section on bromine below).

In these stone troughs a great part of the muriatic acid is condensed. The gases not condensed pass into the base of a coke-tower divided into two sections. They ascend in one of these and descend in a pipe fixed outside the tower, ascend again in the second compartment of the tower, and are thence led through a descending pipe into the chimney. The exit pipe is fitted with a damper to regulate the draught. The second compartment of the tower serves especially to free the gases which pass through it entirely from muriatic acid. According to the arrangement described the gas traverses both sections of the tower in a direction opposite to the descending current of water. It would be possible to dispense with the two external descending earthenware pipes if the two towers were connected above, and the gas were allowed to pass in the second tower in the same direction as the water. Thereby, however, a much less perfect condensation would ensue in the second tower, and a larger descending flow of water would be required.

Where two muffle furnaces are in use with a total weekly yield of 8000 kilos. of salt cake on the system of condensation just mentioned,

15 metres in height and 2·3 metres in the square (interior measurement) suffice for the production of a strong acid. At any rate the condensation is so perfect, that in the second, or "washing tower," which may measure something less in the clear, the acid obtained does not exceed the strength of 1° B., which may be let pass away in each channel, if it is not preferred to let it pass down in the second or condensation tower. The acid from the first tower may be further strengthened in the first trough—in which most of the accompanying sulphuric acid is condensed—with a view to its utilization in the manfacture of chloride of lime.

Particular attention must be paid to the towers when fitted up. They are filled either with bricks or coke, the latter material being preferable on account of its larger surface, greater power of resisting hydrochloric acid, and its less weight. Sometimes a combination of both materials is made, the bricks being placed below and the coke above. In order to distribute the water equally among the contents of the tower we employ either a rocking trough or Segner's water-wheel. The coke must be filled in neither too compact nor too loosely; the former error impeding the movement of the gases, and the latter leading to the subsequent settlement of particular portions. In both these cases the gas selects the more open passages, and a large part of the tower may be thrown out of action. The towers may also deviate from the perpendicular, when the water runs down one side alone, leaving the other nearly dry, and as these parts allow the freest passage to the gases the actual absorbtion becomes very small.

A very convenient arrangement for condensation is the combination of coke towers and Woolff's bottles, introduced at Stolberg and elsewere. The gases escaping from the salt cake pans and muffle furnaces, considerably cooled in passing through a long series of earthenware pipes, are led into a long row of Woolff's tubulated on both sides at a fourth of their height, reckoning from the bottom and connected by caoutchouc tubes well secured with cement; thus the liquid in all stands at the same level. From these the gases enter the coke towers, whence the condensed acid flows back into the Woolff's bottles to be there strengthened by the muriatic acid gas continually streaming over it, and thus reaches the required strength (Hasenclever).

In England the condensation of the hydrochloric acid is carried so far that whilst in the first year of the operation of the Alkali Act,

1·28 per cent. escaped, in the second the loss was reduced to 0·88 per cent., in the third to 0·73, and in many works as far as can be ascertained, the condensation is perfect.

For many purposes, especially in the manufacture of sugar, there is required a hydrochloric acid free from sulphuric acid, iron, and arsenic. Very various proposals have therefore been made for obtaining a pure acid from the arseniferous product. Thus, Houzeau,* in order to obtain the acid free from arsenic, distils the crude acid, adding 0·3 grm. pulverized chromate of potash to 3 litres, and, in order to protect the arsenic acid produced by the liberated chlorine from the reducing action of the hydrochloric acid, he causes during the distillation a continued stream of a solution of chromate of potash of tenfold the strength to be added. The escaping hydrochloric acid gas is freed from the accompanying chlorine by means of copper turnings, and is then conducted into water. This process, however, is scarcely applicable on the large scale, as chlorine is necessarily evolved in very considerable quantities, and its absorption by means of copper is somewhat costly. P. W. Hofmann,† of Dieuze, on the other hand, has successfully introduced the following method for purifying hydrochloric acid: A vessel filled with a doubly perforated earthenware stopper is filled with hydrochloric acid to the extent of one-third, and sulphuric acid of sp. gr. 1·848 is introduced by means of a funnel capable of being closed. The hydrochloric acid gas, which is given off very regularly, is washed in a Woolff's bottle and absorbed by distilled water in a receiver.

The evolution of gas ceases as soon as the sulphuric acid has fallen to the sp. gr. 1·566, in which case it only retains 0·32 per cent. of hydrochloric acid. The sulphuric acid thus diluted is either employed direct in the manufacture of sulphate of soda, or it is re-concentrated, the expense of which amounts to 1 franc per 100 kilos. As 100 kilos. of sulphuric acid thus yield 40 kilos. hydrochloric acid of sp. gr. 1·181, 100 kilos. of pure hydrochloric acid prepared by this process are $2\frac{1}{2}$ francs dearer than the crude acid. Fresenius,‡ however, remarks that the acid thus purified is not quite free from arsenic, the gas evolved containing arsenic at every stage.

(To be continued.)

* Houzeau, *Compt. Rend.* lix., 1025. *Wagner, Jahresber.*, 1865, 251.

† P. W. Hofmann, *Ber. Chem., Ges.*, 1869, 272.

‡ *Journ. Analyt. Chemie*, 1870, 64.

JOURNAL

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FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

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EDITORIAL.

NOTICE.—The publication of the JOURNAL is made under the direction of the Editor and the Committee of Publication, who endeavor to exercise such supervision of its articles, as will prevent the inculcation of errors or the advocacy of special interests, and will produce an instructive and entertaining periodical; but it must be recognized that the Franklin Institute is not responsible, as a body, for the statements and opinions advanced in its pages.

The Technical Education of the Mechanical Engineer.—Amongst the requirements of knowledge by the mechanical engineer, under which title is meant he who should undertake the direction of mechanical construction, not the least important is that he should be thoroughly informed in the capability of the handicraft of the workman. The knowledge of the physical properties of bodies, the mathematical propositions of "applied mechanics," the principles and theory of machinery, the construction, form and adaptation of parts in various machines themselves, with the functions they accomplish, can be acquired, to a great degree, by study; but the capabilities of the manipulations of the workshop or work bench will yet remain a mystery, to be unraveled mainly by experience and observation.

In a general sense in the history of mankind, the question of education, or its methods, is not a new one. Each generation, for itself,

must be taught and must learn, precisely what was learned by the preceding one; and the race in life of the young man will have commenced just when that of his father did. Possibly, sometimes a small increment of knowledge has been gained, and civilization, in its strict meaning of aggregation of people in cities, has taught some one generation lessons in social demands or developments. Education will have followed, and through a series of generations the children will have commenced at a new standpoint, and a new progress in the arts and sciences has been attained. In the arts, this education of the artisan has generally been traditional—from father to son—from master to apprentice; and when, by turbulence and war, the peace-loving and comfortable citizen has been despoiled of his luxuries and comforts, by those who have not known enough to create them for themselves; the unrecorded knowledge has been, for a time, lost; to be acquired again, "under protection of sword." Frequently, the conquerors have protected and employed the workmen, in more or less enslaved conditions; but, with the absence or uncertainty of a free reward, the arts have languished, and have almost, if not entirely, perished—carrying with the loss, the civilization which originally engendered them, and extending the ruin to the victors themselves. A more stable condition of society, where the soldier has not been the ruler, has, in modern times, guarded and fostered the arts and all derived learning; and the last three or four centuries, whose record we have, or are acquiring, has shown a development and growth of the arts and sciences, in unexampled rapidity and magnitude.

The past hundred years alone have witnessed, as seen in the amazing retrospect, the wonderful substitution of machinery for handicraft—of mechanical performance for skilled labor. This has occurred progressively, in the three generations of human life and work which embrace the century, in a kind of geometrical progression for any successive divisions of this period of time.

The apprentice of one hundred years since, acquired by experience the teachings of his master, but applied his labor not wholly to the production of the finished article of trade, but in part to the production of machines which were substituted for his hand tools and hand labor. The grown workman, who was fifteen years later the personator of supposed apprentice, imparted his traditions and acquirements to a new apprentice, who, by the introduction of machinery, was no

longer called upon to exercise all the skill, care or thought, that his teacher had been called to employ, because the *machine* had supplemented his tools; another succession and another followed, each time has the machine gained on hand labor, until now the ability of the mechanic consists more in the use of the machine than of the hand. With this progress of mechanism has followed manufacturing, and much of the teaching of the later mechanics has become in the use of special machines, confined to distinct processes, to the nearly complete neglect of handicraft or artisan skill. Manufactories and machines have called into existence a new class of skilled workmen, who shall have learned how to make available, and possess the ability to bring into novel or repeated practice, the acquisitions in mechanical skill of all kinds; and these men are our mechanical engineers.

The distinguished men in the field of mechanical engineering of to-day, have grown into these positions. The most of their elementary learning has been derived in the workshop, and from the workman, by the traditional method, and their education has been attained in the experience of failure and success which attends new efforts. The more work a man does, the more mistakes he will make; long years of practice have evolved *types* of machines, each detail of which, is an especial result from the labor and intelligence of individual mechanics, and the knowledge of the accomplishment or its methods, yet unrecorded or described, exists only in some directing mind whose capability to apply them constitutes the engineering faculty. The patent records, old and new, cover a small, very small part of the mechanical development of the century, so small that it can almost be said, with truth, that no valuable machine, process or apparatus now is, or ever has been covered by any valid or strictly equitable patent claim—so small that these records are never read either as the total of history, or as a complete exposition of any one appliance in mechanism. Descriptive literature is equally at fault in the completeness and practical application of the knowledge which has been gathered in its pages, so that there remains as the only reliable basis of action by the mechanical engineer, only his *appreciation of the capabilities* of materials, both as materials and in manipulation; the latter being either performed by the workman or by the "*machine-tool.*"

It is easy to see how this knowledge has been acquired by the present holders of it, but it is obvious that the same path is not open

to their successors. The large workshops and manufactories have divided labor, in following out their legitimate end of profitable production, until the mechanic in their employment has become the "operative" or overseer of the operations of a machine, with the least of manual or intelligent effort left to humanity. This operative can scarcely be called a workman, and it is very sure that nothing except the possession of the highest mechanical ability will allow him to become an engineer, even if chance gives him an opportunity to develop the ability; and at all events it is sure that the mechanical engineer of the future who shall rival foreign and other competitors in accomplishments, will have learned in another school. Not only is the *operative* of the special machine thus debarred from attainment of knowledge, but the *workman* in the machine shops, at the smiths' fires, in the pattern room, or the foundry, all in their constancy of labor at their divided branches of industry, are precluded from acquiring general knowledge. Possibly the foreman of a gang of men, or the draughtsman in the office wherein the work is originated, may have the desirable opportunity to witness labor and accomplishment, but the derivation of foremen and of draughtsmen is ceasing to be from the ranks of the operative workman.

Given the educational basis which is now recognized as needful for a civil or mechanical engineer, how is the young man to become a foreman or a draughtsman, in the completion of his course of instruction? Given the ability or executive direction which causes a young man to be selected from out of the group of working operatives to act as foreman; or the mechanical perception which has elevated the youth from the bench to the office desk, how is he to acquire the knowledge of books requisite for him to become a directing engineer? These are the questions to be answered.

There are those who lay great stress upon the value of the old institution of apprenticeship, the return to which is in some way to be supposed to restore the capability of acquirement of engineering knowledge to the present generation, on a footing similar to that possessed by former ones. This view has been advocated very recently to such effect, that a special act of the Pennsylvania legislature was passed at the last session (of 1876), offering extraordinary legal safeguards, and immunities from responsibility, unknown to the old common law, to manufacturers employing apprentices. If these apprentices shall be really taught as of old in the entire art and mystery of their

several occupations, in all that the *master* knows, shall be cared for, bodily and mentally and above all morally, during their apprenticeship, so that when they become journeymen, they will (if they have been diligent youths) be fitted to become masters themselves—not mere laborers—then this law may bear the promise of satisfactory return. But when the obligations of equitable apprenticeship upon the masters, here asserted are admitted, it appears almost certain that the results of this apprentice act, will scarcely fill the expectations of some of its advocates and friends.

In every grade of workshop in England, and especially in the engineers' shops (as the machine shops are there denominated), as well as in the offices of the civil engineers, student apprentices or articled pupils are employed. With regard to the former of these, there are many reasons why a similar practice has not been and will not be followed in this country. The first of these reasons is the comparative absence in England of that destructive rivalry in mechanical business which exists in America. The rates for labor, and the estimated value of the mineral in that country, have been so low, and the application of machinery so much in advance, (at least until recent years of the century) that England has led the world for a market. The established product of an English workshop, has at all times possessed what might be called a good will. Few of them will purposely rival, in the same way, another in the production of what is the regular manufacture of the one, and but the exceptional demand upon the other; and purchasers are yet more chary in the acceptance of work from inexperienced makers. A man can be generous who has an abundance; he can be just, where he is sure of just dealing in return. Perhaps the condition of abundance has more relevance to the subject under discussion than that of justice. Not many American manufacturers would accept educated, clear headed, intelligent young men as student apprentices, to learn from their workmen, their machines and their processes, the art and mystery of their business. Beside this the condition of the student apprentices amongst the workman in one of our shops, may be regarded as too anomalous to the habits of the average American workman or foreman, to be supposable in actuality. The second method for obtaining practical experience—that of the articled pupil—suffices in the office of the engineer, but is far from satisfactory as the method to learn the value of the workshop manipulations to the pupil. In this country, at this

time, there are no articled pupils, and even students in engineers' offices are rarely to be found.

Neither a return to the system of apprentices and masters, nor the adoption of the method of pupilage in an office, presents the least prospect of affording the education of the business engineer in the future.

The simple question follows, why should not a boy be taught practical mechanics in the school? and this question carries with it its own reply. There is no reason why constructive mechanism should not go hand in hand with applied (mathematical) mechanics, or why manipulation should not be taught at the same time with the properties of materials in the lessons of the school. In accordance with these views, within the past few years, several of our American colleges have established classes and professorships in conjunction with their courses in technical learning. Amongst these, the Sheffield School at Yale College, New Haven, Conn.; the Cornell University at Utica, N.Y.; the Stevens Institute at Hoboken, N. J.; the Free Institute at Worcester, Mass., are prominent examples. Other technical schools have, in different degrees, pursued the handicraft culture of their scholars.

But in thoroughness of teaching, and especially in exhibition of attained success, there is now presented to the admiration of all mechanics, at the Centennial Exhibition, a special example from a foreign land, which should induce emulation. The exhibit made by the Imperial Technical Schools of St. Petersburg and Moscow, demonstrates the feasibility of so educating pupils, that when they pass out from the doors of their school, they will have become at once scholars in their learning from books, and proficients as educated workmen in the varied branches of the workshop. These young men on leaving college are quite as able to demand work as journeymen, as the average of mechanics when out of their time, for they will have—must have—performed by unaided effort, such feats in workmanship, within limited times for accomplishment, as none but skilled workmen can do. The demonstration of the Russian schools is, that this practical instruction can be given in the fullest range and quality, not only without interfering with, but positively to the advancement of, other indispensable professional studies. From such an example there should not be the least hesitancy in following the same course in the technical education of the American mechanical engineer.

Dry Dock.—For many years the commerce of Philadelphia has felt the great want of proper facilities for docking large vessels for repairs, there being no private docks except two small floating ones, quite too small to accommodate vessels engaged in our foreign trade.

The floating dock at the old navy yard was sometimes allowed to be used for merchant vessels, but the formalities and uncertainties attending its use, the remoteness from ship yards and shops made its use expensive and unsatisfactory.

To meet this want Messrs. Wm. Cramp & Sons determined to construct at their ship yard on the Delaware, at the foot of Hanover Street, a stationary Dry Dock of sufficient size to take in the largest vessels that enter this port.

The water of the river at this point being fresh, there is no danger to a wooden structure from the teredo or shipworm, and therefore, in order to reduce the first cost it was determined to construct it entirely of wood. The plan adopted was that invented by Mr. J. E. Simpson, who was also the constructor.

The dimensions are as follows: length from head to gate, when in position, 430 feet; length of keel blocks, 420 feet; width at bottom amidships, 45 feet; width at top amidships, 111 feet; width at gate, 70 feet; depth, 26 feet; depth below high tide, 23 feet.

After making the necessary excavations the foundation was formed by driving 12-inch iron-shod oak piles about 10 feet into the disintegrated gneiss rock which underlies that locality. These piles are placed about 4 feet apart in both directions, over the entire bottom, except along the centre under the keel blocks, where there are four touching each other in each row. To the top of the piles are fastened 12-inch timbers running across the width, and on these is laid the floor of 3-inch plank.

To form the sloping sides, piles were driven perpendicularly, in rows corresponding to those in the bottom, and cut off to a line conforming to the proper inclination. On the top of the piles were secured timbers running longitudinally, and to these were framed and fastened other timbers running down the slope, and fastened at the foot to the bottom timbers. To these sloping timbers were fastened the planking of the sides, consisting of timbers, the cross section of which is a right angle triangle, with one of the acute angles cut away for a few inches, and so placed as to form steps of about eight inches rise and the same tread. Several rows of sheet piling were driven

across under the dock to prevent the water from the river finding its way underneath, and tending to float it.

The gate is an iron boat of sufficient length and depth to fill the gateway. The keel, stem and stern post project evenly about six inches, and are made to fit in grooves in the bottom and sides of the gateway. These grooves are lined on their inner sides with rubber, so that when the pressure comes against the gate a water-tight joint is formed.

The gate has tanks to be filled with water to sink it to its position, and is provided with pumps to exhaust them, and also valves to admit water to the dock when it is to be filled.

The dock is now in daily use and will prove to be a great advantage to the shipping interests of the city.

Removal of the Obstruction at Hell Gate.—Common report anticipates the explosion which is to destroy the piers in the mine at Hell Gate channel as of probable occurrence on the 5th of September ensuing, and there seems to be a general expectation that the event will be a startling one. But unless some error is made in the estimation of the power of the explosive agents, the chances are that it will prove one of the most quiet and tame transactions ever witnessed where the resulting effect will not have been commensurate to but one-tenth or one-twentieth of the present anticipated one in magnitude. As an engineering exploit the success will be measured in some considerable part by the absence of violent disturbance. If the destruction of the piers and the decadence of the shell of rock now covering the excavated ruins, could be as quietly performed before the spectators on the shore and out of the water, as an eclipse of the moon is to persons inside of a closed up room, the success of the operation would be undoubted. It is especially desirable that the debris should not be removed from its present locality, but simply deposited on the floor of the present excavations, from whence it can be removed without interrupting navigation. Unless some enthusiastic spectator fires a Chinese cracker, the Quaker meeting of removing the obstruction is likely to pass off in relative quietness, and the disturbance of water, except the escape of a volume of gas for a moment, will, in all probability, be less marked than that which occurs at Hell Gate at any half tide from the meeting of the currents.

NEW METHOD OF IMPROVING HARBORS.

[From *Engineering News*, August, 12, 1876.]

For many years it has been a serious question how to preserve the harbors on our Gulf coast. The conditions involved are in many respects similar to those on our northern lakes, the chief thing to be guarded against, being the closing of the mouth of the harbor or bay by the sand swept along by the littoral current. Of course the device usually adopted in such cases is some form of the parallel jetty, which, checking the current along the shore left the space between the jetties to be scoured out by the action of the tides and local currents or to be dredged where these were absent.

The storms of the Gulf are often quite violent, and structures of more than ordinary strength are required. All the ordinary forms of timber crib-work or pile jetties are precluded from the fact that they are soon destroyed by the teredo navalis, no method of preserving timber from their destructive ravages having proved efficient. Breakwaters or piers made of stone are not practicable from the great distance it would be necessary to transport the stone. Concrete blocks are quite expensive and only warranted when there are immense commercial interests to subserve, which condition does not exist at present on the Gulf coast. It is very doubtful, from the ease with which sand finds its way through the Port Said breakwater, if loose blocks of Concrete would be efficient, or if they would not entirely settle out of sight, as the Gulf sand is quite finely comminuted and well worn. At any rate some less expensive method must be found or else the number of Gulf harbors must be comparatively limited.

In 1874 experiments were commenced on a new method of construction at Galveston which is destined to be the most important Commercial City of the Gulf and to whom the preservation of her harbor is of vital importance.

We have watched these experiments with great interest and are pleased to record that they have met with such success as to warrant the inference that the harbor question of the Gulf States is already solved, and by a method of construction withal, quite economical.

The method adopted is by gabions* placed in rows so as to form a training wall or jetty. The final form and method of construction

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* The mode of protecting the gabions from the teredo does not seem to be clearly stated.—NOTE BY ED. F. I. J.

WISNER & STRONG,

BALANCED SLIDE VALVE.

Fig. 1

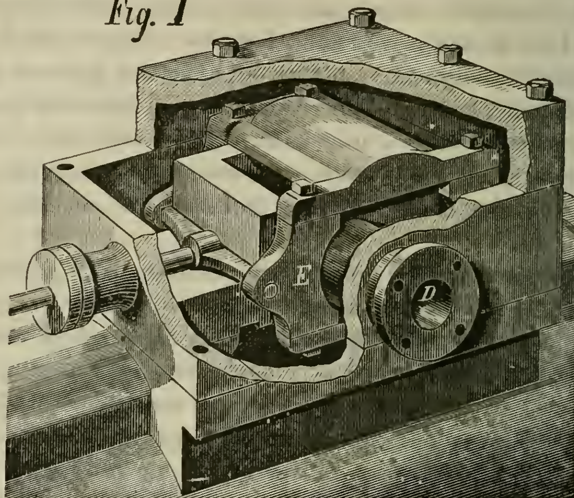


Fig. 2

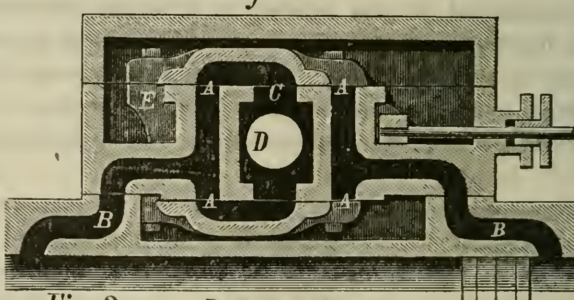
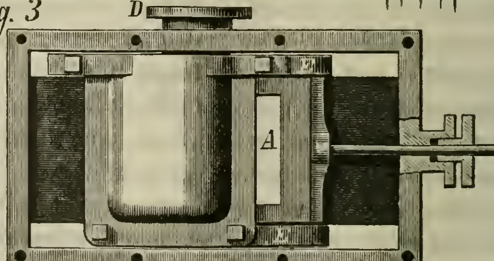


Fig. 3



Improved Balance Slide Valve.—Wisner & Strong, Pittston, Pa. Centennial Exhibition, Machinery Hall, south side, sec. B, column 72.—The accompanying wood cuts show a slide valve arrangement, offering some points of superiority over the saddle plate, or relief method of effecting the balance. The section Fig. 2, gives a distinct view of the way proposed to be used, which is a pair of valves covering seats on opposite faces of a separate channel piece, this channel piece in this case being the main steam chest casting. Channel ways at the end of the separate piece (on one face), come in line with those of the cylinder, so that the steam passages to the cylinder lead from double valve seats in the same way, only through a slightly lengthened course, as from an ordinary seat cast upon the cylinder. The two valves which rest upon these faces are held apart by distance pieces at their sides, and are thus made to balance each other. The outer valve of the two is secured to the distance blocks by bolts having springs under the locked nuts, so that it is as free to lift off its face in event of water in the cylinder, as the ordinary slide valve. The gain in the removal, of the cooling effect of the exhaust from the side of the cylinder—where the exhaust passage is commonly formed—nearly, if not quite, compensates for the extra length of passage which the arrangement demands; while the double valve gives all the advantage of a grid-iron valve, with abundance of room in the chest for an efficient lap, which conditions are nearly unattainable with a double-ported valve, moved by a single eccentric, for ordinary length of cylinders. The balancing is nearly perfect, and the valves have been found to be at first quite as tight as any single valves; and after two years' running have shown no signs of wear, preserving their original tightness.

These slide valves will work, with the least of power, with certainty of action at all times; expansion or contraction not affecting the bearing on the faces, the relief being equally good at starting the engine, to what it is when fully at work, with steam at high temperature. Locomotives or hoisting engines with such valves can be reversed, under any pressure of steam, with perfect ease and safety. An Engine at the Centennial is now running a line of shafting and working under 50 to 55 pounds pressure of steam. This engine has its cylinder 16 inches in diameter by 30 inches stroke, and the valves have 150 square inches of covering surface. These valves are operated by means of a valve-rod 3-16ths of an inch in diameter, in lieu

of the usual size of about $1\frac{1}{4}$ inches diameter. It is scarcely necessary to call attention to the economy of original construction and finish, of this plan for balanced valves, and the facility of access if repair should ever be required ; but these are obviously not the least of its merits.

FUEL AND ITS USE.

By Prof. H. Fritz, Zurich.

[From *the Journal of Applied Science*, August 1, 1876.]

Although frequent attempts have been made to render the use of fuel as advantageous as possible, the results are far from satisfactory, as only part of the heating power is utilized. The difference between theoretical and effective heating power for various sorts of fuel may be seen by the following table, which gives the number of pounds of water evaporated by one pound of fuel.

Fuel.	Heating Power.		
	Theoretical.	In Steam Boilers.	In Open Boilers.
Petroleum	16·30	10—14	....
Anthracite	12·46	....	....
Coal	11·51	5·2—8	5·2
Charcoal	10·77	6—6·75	3·7
Coke	9—10·8	5—8	....
Brown coal	7·7	2·2—5·5	1·5—2·3
Peat	5·5—7·4	2·5—5	1·7—2·3
Wood	4·3—5·6	2·5—3·75	1·85—2·1
Straw	3·0	1·86—1·92	....

As regards the heating of steam boilers, Mr. Thompson found, by a series of experiments, that, on an average, only forty-seven per cent. of the theoretical heating power of the fuel is utilized, the remainder being lost through imperfect combustion, radiation, and other causes. Since portable engines have been arranged for straw burning, this fuel has become of great importance for agricultural purposes. Trials at the Vienna Exhibition proved that one pound of straw is capable of evaporating from 1·81 lb. to 1·97 lb. of water into steam of seventy pounds pressure and 305°6 Fahr. Compared with Thompson's figures for other fuels, straw would seem to give more

work than even coal; but the trials in Vienna were made with Exhibition engines, and under the most favorable circumstances. Amongst the other caloric engines tried up to the present time, only those working with hot air, exploding gas, and exploding vapor of petroleum have proved of practical use. The following table shows the comparative merits of different systems :—

Air Engines.	Pounds of Fuel per Hour, and H. P.	Relation between Effective and Theoretical Work of Fuel.
Belou	3·3—4·84	6·0—4·1
Leawitt	6	3·5
Lehmann	10·12	1·9
Leauberau	9·9—13·15	2·0—1·4
Ericsson	11—16·5	1·8—1·2
Gas Engines.	**Quantity of Gas reduced to Coal in lbs.**	
Otto and Langen	3·96—6	5·0—3·5
Hugon	9·9	2·0
Lenoir	9·9—12	2·0—1·8
Petroleum Engine.	**Petroleum in lbs.**	
Hock	1·65—2·86	8·4—4·6

Comparing the different steam engines with these motors, it is found that as regards work they are nearly equal, or rather, the duty varies for steam engines and other caloric motors almost between the same limits. To show this, the following table is arranged according to the work of the different motors :—

	Per cent.
Small high-pressure engine without expansion	1·8
Air engine, Ericsson	1·8
" Leaubereau	1·8
" Lehmann	1·9
Gas engine, Lenoir	2 0
" Hugon	2·0
Portable steam engine	2·8
High-pressure steam engine with expansion	3·0
Air engine, Leawitt	3·5
" Belou	4·1

Condensing engine with expansion	4·5
Gas engine, Otto and Langen	5·0*
Petroleum engine, Hock	8·4
Large steam engine, best make	9·0

Although, according to this table, the work of high pressure steam engines is less than that of gas or air engines, the cost of fuel for the latter still exceeds that for steam engines from 2·5 to 5 times, a circumstance which explains the fact that, notwithstanding the many advantages of air or gas engines, they are not able to replace the ordinary high pressure steam engine.

Book Notice.

TREATISE ON THE MECHANICAL THEORY OF HEAT.—R. S. McCulloch, C.E., Professor of Mechanics, Washington and Lee University, Va. 12mo, 288 pp. D. Van Nostrand, New York, 1876.

It would be difficult to find a parallel example of so excellent, thorough, and exact a text book, as completely wanting in inductive arrangement; while at the same time it is not known where to look for any corresponding presentation of the dynamics of heat of equal clearness or accuracy. If, however, it is assumed that the book is a résumé of lessons—that it has followed, and accompanied courses of physics and practical mechanics, in which the several propositions have originated, then the mathematical demonstrations in some order of sequence, will have become invaluable aids to the learner, and this recapitulation in the groups chosen, will be highly advantageous.

In the preface of the work the author speaks of the retrogression "of scientific, as well as classical, education in this country, and superficially is the fashion of the day," by way of apology for the use of the concise language of modern mathematics. Without denying the decline of Greek scholarship—Is not the publication of this work in this country at all an indication of progress? The first page of notation, which is not that of the "fluxional calculus," is evidence of the growth of English mathematical science during the past fifty years.

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* This rate of actual economic effect for the Otto and Langen engine is delusive in some regards. First, there are obvious limits of size for the Otto and Langen principle of action when reduced to working practice, so that the relative economy would be affected (impaired) materially when an engine develops any large quantity of power, say above 8 to 10 horse power, and second, the Otto and Langen engine is especially economical in the performance of irregular labor, in which regard it appears to present striking advantages over any other engine known.

The English reports of this engine also place it higher in the scale than is shown on this table.—See JOURNAL OF THE FRANKLIN INSTITUTE, vol. C, p. 262. (Note by ED. F. I. J.)

May there not be a scientific one-sidedness quite as objectionable as an unscientific "superficiality?" For the mathematician to insist that the mechanical theory of heat is purely a question of thermo-dynamic functions, is probably as untenable ground, as the proposition that the science can be investigated or understood without them. The facts must exist and should be stated, previous to the investigation into their causes and effects.

The mechanical theory of heat can be clearly given. It is the theory that the motion of a body may be changed into vibrations of the molecules which form that body—that these vibrations constitute the condition which is called heat—that heat pervades, and is incident to, all material substances—that heat transfers, with a tendency to equality of vibratory power, from one body to another (although the value of a vibration in one body differs from that in another)—whence generally, the putting in motion of any body is always attendant with the abstraction of definite quantity of heat, (molecular vibration); and the dispersion of a corresponding amount of heat, attends the coming of a body to a state of rest.

Of this statement of the mechanical theory of heat, the molecular vibration is of course hypothesis—no direct experiment can show it—but it certainly fills the requirement of accounting for the preservation of continuous motion in the universe; and by analogies with acoustic vibrations, which can be exhibited and have been studied, many, if not all, of the phenomena of heat can be reduced to mathematical laws. The absolute generation of heat by the application of force—by the retarded motion of the body, is, however, an established fact in physics, and was first announced by Rumford, 1790-8, and has since been determined with acceptable accuracy by Joule, 1843 9; and although older mathematicians, beginning with Huyghen, 1690, and going through a list of distinguished names (amongst which Newton's appears as an opponent to the theory) down to 1850, advocated a vibrating theory for light and heat, yet it was not until 1849 that Rankine and Clausius and Thomson enunciated, as an accompaniment to Rumford's convertibility of force to heat, the theory of thermo-dynamics.

Perhaps there is not in all of English scientific literature a better use of language than that which, in Rankine's Steam Engines and Prime Movers, commences Chap. 1, of Part III, "of relations amongst the phenomena of heat." Beginning with the most elementary statement, the perspicuity of words has left no uncertainty or inaccuracy for the most critical or advanced student, and step by step the reader is led to the results which Prof. McCulloch has expressed in another order, and somewhat more at length. In point of fact, Prof. McCulloch's book is the acknowledged production of the study of Rankine, Clausius, Thomson and Hirn, with reminiscenses of Carnot, Clapyron, Fourier, Fresnel, Regnault and others; and in this regard it is the book for the professor rather than for the pupil.

Still, one cannot help remarking what an admirable book would have been produced, if the experimental and mechanical foundation had been established in an inductive order.

The want of assertion of some such basis leaves in many places an opening to question the mathematical results. The writer of this notice for instance, is by no means prepared to accept Hirn's conclusions and resulting adabiatic curve. A careful examination of Rankine will show that he did not place the most implicit reliance on the indicator in his efforts to show the absolute useful effect. He uses the diagram in the form of an indicator, and with all propriety, but never a card of actual engine performance. There are too many contingencies. The indicator is really an admirable instrument for the steam engineer, or a mechanic, in showing place of valves, leakages of valves or piston etc., etc., but it demands great skill to make it exhibit these conditions. The instrument itself, when of the most delicate make is open to criticism; and when jacketed cylinders are employed, the distortion of steam line for the low pressure is, with the inevitable leakage of the piston, out of all possible bounds of assumable error There are some other propositions, which may be open to doubt. The phenomena exhibited by water when heated above the boiling point, and the spheroidal (so called) condition of water—both of these had another explanation given in the pages of our JOURNAL.*

In one regard beyond all others, this excellent book is noteworthy. While it is a treatise on the most positive of all branches of study, an exposition of the reasoning faculties only, it is prefaced and concluded in an acknowledgment of the insufficiency of mere human understanding; and the averment that the most profound researches of the human intellect, are but contemplations of fragments of the infinite wisdom which rules the universe; and it points from the revelations of nature, to those which have been given to us more directly and positively.

Cornish Pumping Engine at Providence, R. I.—The large engine (one of the largest in the country) which has been erected at the principal water station for this city, on the Pettaconset river, has commenced to run in a highly satisfactory manner. It is pumping all the water needed for the present supply of the city, a quantity within 4 million gallons each day, moving quietly at about seven and a half strokes per minute—equal to $7\frac{1}{2}$ millions of gallons in 24 hours, with the steam following the piston 15 inches (11 feet stroke). The reported duty is 95 millions of pounds of water lifted one foot per one hundred pounds of coal supplied to the boilers.

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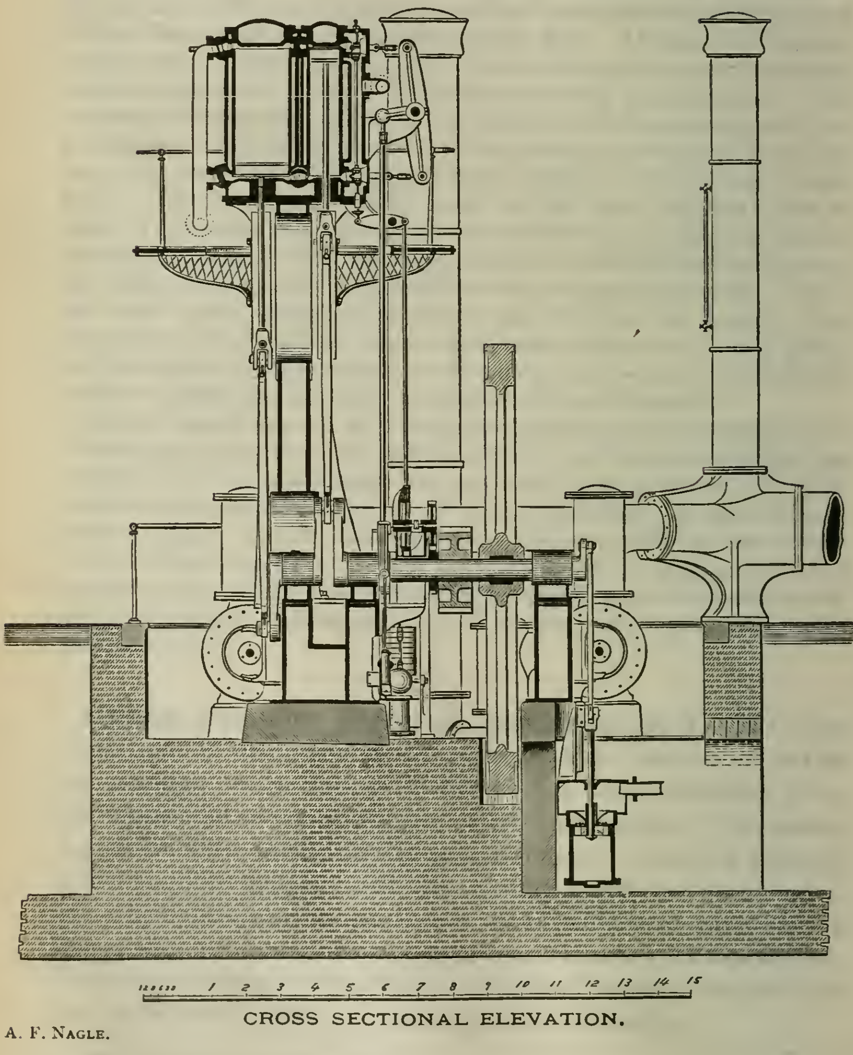
* See present volume, page 86, *et seq.*

PUMPING ENGINE

FOR THE

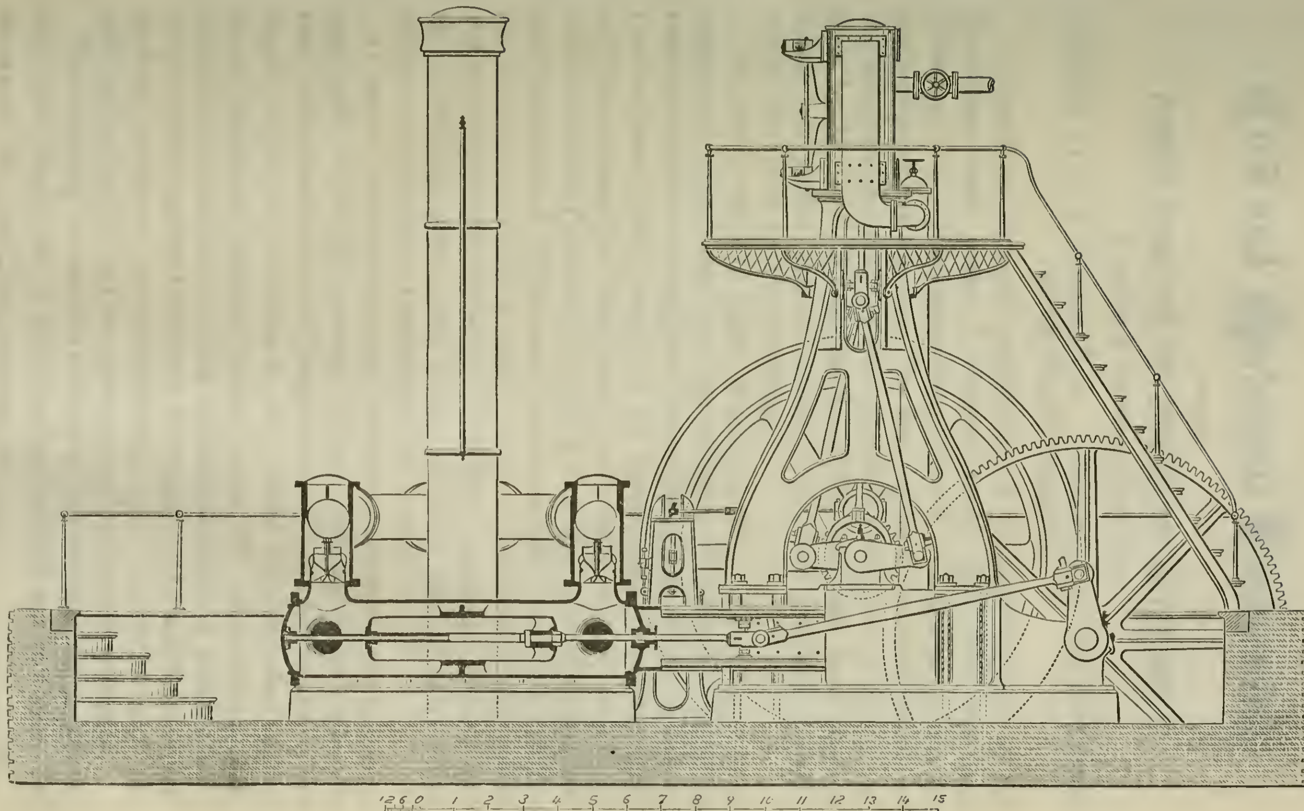
PROVIDENCE, R. I. WATER-WORKS.



CROSS SECTIONAL ELEVATION.

A. F. NAGLE.

PUMPING ENGINE FOR THE PROVIDENCE, R. I., WATER-WORKS.



A. F. NAGLE.

FRONT ELEVATION.—Sectional through Centre of Pump.

Civil and Mechanical Engineering.

PUMPING ENGINE FOR THE HIGH SERVICE WATER SUPPLY

In the City of Providence, Rhode Island.

Designed by A. F. NAGLE, M.E. Constructed by the Providence Steam Engine Company.

In accordance with the specifications of the chief engineer of the Providence water works, J. Herbert Shedd, C.E., there was completed and tested in December last, a second, or duplicate, engine for the high service in this city. The first engine for the performance of the same service, under the same conditions, had been designed and built by Mr. Geo. H. Corliss, in 1872-'3, and had been running nearly two years; and this second engine was provided as a substitute in case of need or preference.

The contract for the engine stipulated that "the engine is to be capable of raising with ease five millions of gallons of water in twenty-four hours to a height of one hundred and twenty feet above [the low water level of supply to the pumps] under a possibly varying [level of supply of forty feet]; is to work smoothly under the above conditions [as to lift of water], and also when [raising] but three hundred and fifty thousand gallons in twenty-four hours [under like conditions as to lift of water]; is to be attached to the suction and force mains now located in the station; is to pump directly into the distributing pipes; and is to perform a duty of seventy-five million foot pounds per hundred pounds of coal."

It will be noticed that these contract requirements of capability, apparently call for the greatest and least velocities of the engine, to vary as fourteen to one, and the greatest and least performance of the engine, to vary as twenty-one to one. These demands when applied to any continuous movement steam engine are sufficiently onerous, and it may be questioned if the accomplishment is a possible one; but even these apparent demands are exaggerated when the condition of direct connection to the distributing pipes is included with the daily limit of supply and the possible varying head of resistance.

The capability to raise five millions of gallons with ease in twenty-four hours, means that at times the engine shall run at a rate—for

some minutes—which would supply, if continued, six millions in twenty-four hours, while the delivery of three hundred and fifty thousand gallons in the distributing service in any twenty-four hours could hardly call for a speed of engine, at midnight, for instance, that would exceed the rate of ninety thousand gallons, if continued the whole time. These figures give the variation of speed of engine between the greatest and least requirements as nearly seventy to one; and the variation of greatest and least *performance* as one hundred to one.

Without entering into the question of the possibility of accomplishment, in this notice, it will only be said that the engine did not fulfil the specifications (neither did the Corliss engine) to the letter of the contract. But by means of a relief valve, a quantity (not stated) of water, which, it may be assumed, was considerably in excess of the three hundred and fifty thousand gallons in the twenty-four hours, was permitted to escape from the distributing pipes, (under the resistance of flow through the aperture of this valve, and discharge into the supply mains), to be pumped over. In this manner the necessary constancy of resistance was made to accompanying extreme variations of demand, so that when the requirement was exceedingly small, the regular work provided by the "relief valve" would be sufficient to keep the engine in motion with comparative smoothness.

This evasion of the terms of the contract being allowed, the testimony of the experts (Chas. Hermany, C.E., J. B. Francis, C.E., and Prof. Chauncey Whitaker) shows that the engine would command the exigencies of the service for which it was intended, which really are the maximum supply of five millions of gallons in twenty-four hours, with a minimum supply of whatever may be abstracted from the water pipes at any time. And this irregular demand was met even to the maintenance of pressure when the fire hydrants of the district were put in use suddenly and without communication with those employed about and running the engine.

The usual stipulations as to quality of material, workmanship, strength of parts, and changes of plan, delivery of material, advances of money during construction, protection from liens on work or material, etc., follow in due course in the contract.

With these clauses, there is one which has become usual with some engineers, whereby the contractor is made to defend the city, its officers and agents, against all patent claims or demands, under a

bond of indemnity. If this condition bears the restricted sense of subjecting the contractor to make payment for the use of anything which may be patented in the construction of the work only, limiting the obligation to the profit he may derive as a constructor from such use, as against the use of well known unpatented devices, it is open to no reasonable objection; but if it means that the contractor is to bargain to make himself liable for the value of all or any patented arrangements, whereof the city of Providence may have had the advantage or profit in use, and which patented arrangements the city officers have procured to be made for the city, then the condition is onerous and unfair in the extreme. Under this last rendering the unfortunate contractor would be required to defend, knight errant fashion, against all comers, while the city authorities can foster, encourage or default in the litigation, wherein he may be liable to serious loss, without having the least valuable consideration for his liability.

The engine was to have a duty, as tested by a board of three experts, of "at least seventy-five millions of foot pounds per one hundred pounds of coal, when delivering two million gallons in twenty-four hours against a head of one hundred feet." "The conditions of the trial are to be similar to those adopted in the trial of the Lynn Pumping Engine, in December, 1873."

The boilers and appurtenances, together with the engine foundation, were embraced in the terms of proposals, and were part of the contract.

The price for the whole was fifty-four thousand dollars, conditioned on performance as above, with a requirement to remove the engine and all, if the stipulations of the contract were not met.

The essential feature in the Lynn trial was the establishment of some value of fuel by the use of selected and picked anthracite coal, that would yield about 10 per cent. only of ashes, or 90 per cent. of combustibles.

The test of this engine has not been yet reported in detail, but a summary or result is stated by the experts: "The engine pumped at the rate of a little more than two million (2,000,000) gallons per twenty-four hours by weir measurement, and made a duty of 84,637,245 foot pounds per hundred pounds of coal consumed.

"This work and duty were obtained during a continuous run of fifty-six hours, fifty-one (51) of which were selected by omitting some

hours at the beginning, and some at the end of the trial, for which fifty-one hours the calculation is made; all the coal put into the furnace was charged to the engine, and no deduction made for clinkers, ashes or cinders." *

On the basis of the report of the experts the engine was accepted, and a settlement made with the city, subject to the guarantee of the contract of "the strength as well as the quality of the materials and workmanship of all the parts, and the making good on the part of the contractor, at his cost, all outlays or injuries caused by defects in the same during first twelve months of working the engine," a responsibility which (under the circumstances of the engine, with its duplicate to be operated if it is thought proper) may not be relieved for the next twelve years.

The engine, which has been found to conform to these stringent requirements, is shown in elevation and cross section on the accompanying cuts. It is of the vertical, double over head cylinder, compound type, usual for propeller engines, with a double crank shaft, and opposite connected cranks. The main shaft is led off on the high pressure side, and carries a fly wheel of considerable weight, and has behind the back bearing a half-stroke crank, which gives motion to the piston of the air pump, and preserves the vacuum in a jet condenser. On the main shaft is a pinion which communicates motion to the pumps through a gear wheel upon a second crank shaft. The pinion and gear bear the relation to each other of one to five. There are two horizontal pumps, one on each side of the bed-plate of the vertical engine, driven by right angle cranks at the rate of one stroke of the two pumps to each five strokes of the engine. The pump valves are double beat, there being one suction and one delivery valve at each end of each pump. The high pressure cylinder is eleven inches, and the low pressure one is nineteen inches in diameter; the stroke is three and a half feet. Both cylinders are steam jacketed by live steam.

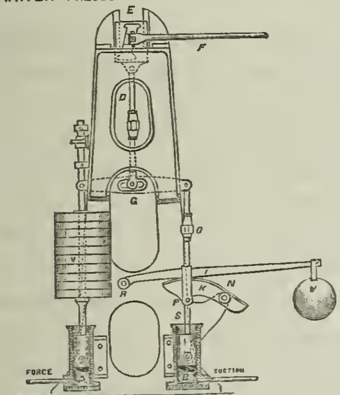
The admission and emission of steam is effected by three separate gridiron slide valves at each end of the two cylinders, which are moved on their seats by sliding cams, having a vibratory action. These cams are worked, although not directly, by a single eccentric; and by the motion given to the valves; the first valve admits steam for the high pressure cylinder; the second valve serves for the exhaust valve

* If the whole time had been taken, the result would have been a little *more* favorable.

for the high pressure and an admission valve for the low pressure cylinder; while the third valve is the exhaust valve from the low pressure cylinder to the condenser. The flow of steam in the high pressure cylinder being controlled by a governor, which regulates the motion of an auxiliary cut-off valve, on the back of the steam valve.

The automatic arrangement for adapting the speed of the engine to the varying requirements and conditions of the service, consists of two cylinders, into one of which water is admitted from the suction side, and into the other from the delivery side. The varying pressures of water in these cylinders, resulting from the increase or decrease of the supply on the one hand, as compared with that in the delivery on the other—so acts on the fulcrum of the connecting lever between the two cylinders as to operate the cut-off, and adapt the supply of steam and the consequent speed of the engines to the then existing circumstances. This governing apparatus has not operated quite as successfully as could be wished, as the effective power for performance of the work of moving the position of the cut-off cams given at the instant of increase of pressure from 119 to 120 feet head of water, is scarcely large enough to be available, and the friction resistance of the plungers is too great a disturbance to the delicacy of action of the pressure.

WATER PRESSURE REGULATOR



The fly-wheel is thirteen feet in diameter and weighs eleven tons. As the speed of the fly-wheel is five times as great as that of the pump shaft, the effective value of momentum in preserving the uniform velocity of the engine, is twenty-five times that which it otherwise would have been.

The pumps are seventeen inches in diameter, and have a stroke of four feet. The consequent displacement of the two pumps is 271,440 gallons each twenty-four hours; whenever a double stroke (or revolution) of the *pair* of pumps is made per minute. The requisite *average* speed for the specified quantities to be delivered was, therefore (without allowing for loss by leakage), eighteen and two-tenths revolutions for the greatest, and one and three-tenths revolutions of

the pump shaft for the least quantities, per minute. The corresponding velocities of the engine were ninety-one revolutions, and six and a half revolutions per minute. The experts limit their report as to the smooth running clause to "It did run smoothly while performing this work," *i. e.* 2,000,000 gallons, or thirty-six and four-tenths revolutions of the engine per minute.

On the whole this engine of the high service at Providence can be confidently accepted as one of the most satisfactory solutions of the problem of the direct water supply to a distributing service, without the accompaniment of reservoir or stand pipe.

The boilers provided with the engine were two in number, each with about twenty square feet of grate. They are of the ordinary fire box, flue-and-top tubular type, of American river or coast steamers of small size. As might be supposed, they are not very self-acting to meet vicissitudes of requirement of 100 to 1, nor very economical in evaporative effect of fuel for slow rates of combustion.

A statement made in the Providence *Evening Bulletin*, Aug. 3d, is the authority for the following comparison of performance in actual service between the two engines.

For the week ending July 23d, 1875, the first engine pumped 3,320,055 gallons of water, and consumed 26,610 pounds of coal.

∴ This performance is equivalent, if the water was lifted to full pressure from the least level of water supply (an empty reservoir, or 120 feet water column pressure), to 12,482,000 duty, or if the water was lifted only 80 feet high, 8,322,000 duty, or water lifted one foot high by 100 lbs. of coal.

For the four weeks ending the same date, the same engine pumped 13,999,095 gallons of water, and consumed 110,262 pounds of coal.

∴ This performance is equivalent to 12,693,000 duty for the high lift or 8,642,000 duty for the low lift.

The corresponding time of year and date—July 23d, 1876—the second engine—that under discussion in this article—has pumped for the week 4,851,600 gallons of water, and consumed 6,400 pounds of coal.

∴ A performance which reduces to 75,806,000 maximum, or 50,535,000 minimum duty.

For the four weeks ending July 23d, the second engine is stated to have pumped 19,792 000 gallons, and consumed 25,495 lbs. of coal.

∴ A performance which reduces to 77,613,000 greatest, or 51,742,000 least, duty.

How much was pumped to waste through the relief valves was not stated, but possibly it was an equal proportion on the two engines; the difference of quantity of water pumped is accounted for by the increase of water supply to the district. On the four weeks' service the last engine appears to be about 6·11 times more efficient than the first.

Errata.—Insert on page 123, vol. CII, at end of line 18, "motion of the," so that the clause of the sentence will read "that the motion of the point of attachment to the main valve-rod ceases."

MEMORANDA RELATING TO TWO 90-FEET CHIMNEYS FOR SIEMENS' HEATING FURNACES AT THE EDGAR THOMSON STEEL WORKS.*

By P. Barnes, Resident Engineer.

[Extracted from the *Engineering and Mining Journal,* June, 1876.]

Exact accounts have been kept of the cost of these chimneys, and it may be a matter of some possible interest that the plans and details of cost should be laid before the Institute. The statement of cost herewith submitted does not give minute particulars of the weights or quantities of material used, although these are noted upon the company's books.

Reference being made to the accompanying drawings, it will be seen that each chimney has an external shell of sheet iron, which rests on an iron base plate, and is thus anchored to the masonry foundation.

They are identical except in the depth of the concrete formation. One of them (North) had to be put in the bottom of a slight valley on the premises, while the other (South) stood on higher and solid ground. Flues were led into the chimney base from two directions, one being large enough for two furnaces.

The base was carried eight feet above the general level of the yard, partly for appearance sake, and partly to keep venturesome boys from climbing up the ladder on the outside.

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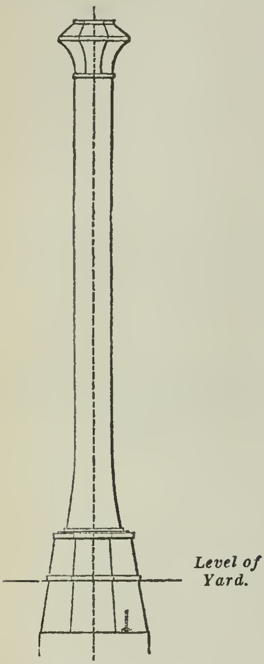
* A paper read before the American Institute of Mining Engineers, at the Cleveland Meeting, October, 1875.

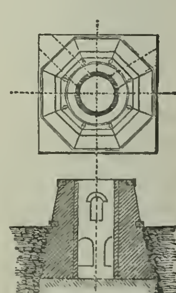
The whole base from the level of the flues was made of red brick grouted in cement, chiefly for the purpose of utilizing a large lot of soft brick that had accumulated at the works. The anchor bolts were hung in place before the brickwork was commenced—the washers resting upon the concrete—so that the total weight of the brickwork is utilized in securing the stability of the chimney shell. At the level of the ground in the yard, a belt course, and upon the top of the base, a coping of sandstone were laid; and upon the latter the iron base plate, in four pieces, was bedded in cement.



Elevation of Base and Shaft.

A side flue lined with firebrick was put in, leading, above the belt course, into the central flue, both to give access to the interior, and to build a fire in, when needed to secure a more perfect draft. The shell was made in 4 feet courses, the lower ones being tapered outward to give a broader base upon the plate. The first course was made of 5-16 inch iron, the next four of 3-16 inch iron, and the remaining upper part of $\frac{1}{8}$ inch iron. A light ladder was put upon the outside, and carried entirely over the top. The finish at the top was made of No. 22 galvanized iron, and painted inside and out.

The interior lining was made of common red brick, laid in lime mortar, and it is 4 inches thick, except at the bottom, where it is thicker, to suit the enlarged diameter of the shell.


Section of Base.

The shell was put together complete while lying on its side upon the ground, and hoisted into place in one piece. This was found, even for so light a weight, to be more troublesome than was anticipated, although no real difficulty was experienced. The cost of erection, however, was slightly greater than really need have been incurred.

All that can thus far be said of the actual performance of these chimneys is that they give a tremendous draft, and that as yet they have not been at all shaken by the wind.

COST OF SOUTH CHIMNEY.

		per cent. of cost.
Excavation	$132	·032
Concrete-stone and labor . .	264	·064
Cut stone " " . .	267	·065
Cement—total used . . :	230	·056
Lime " " . . .	53	·013
Sand " " . . .	57	·014
Anchor bolts	57	·014
Castings	242	·059
Red brick	629	·153
Bricklaying, foundation . .	242	·059
" lining . . .	197	·048
Sheet iron shells . . .	1,190	·292
Paint	29	·007
Labor of erection, etc. . .	444	·108
Teaming	103	·025
	$4,136	1·009

DISCUSSION.

Mr. Metcalf said that he had recently built a brick chimney containing 143,000 brick, and that the cost was less than $3,000. The brickwork was 31 in. thick at the base and 13 in. at the top. Every three feet, flat iron rings, 2 in. by ⅛ in., and 18 in. larger in diameter than the interior of the flue, were inserted, set on edge. The painting of iron stacks is a serious objection to them, since the paint must be repeatedly renewed. He had found the best and cheapest paint to be common soot with the light oil from the refineries, costing about ten cents a gallon. It does not contain acid which, when tar is used, attacks the iron perceptibly.

Mr. Pearse said that the reason iron chimneys were first built was to avoid the cracking of brick chimneys when driven hard. The Pennsylvania R.R. had built a chimney shaped like a double star, the points acting as buttresses. He preferred the iron chimney with square base plate, to get a leverage at the corners, and said that, having built several, the first used in this country, he had gradually reduced, with safety and success, both the thickness of metal and lining—the metal to ¼ in. at bottom and ⅛ in. at top, and the lining to 4 in. firebrick at bottom, then red brick, and 2 ½ in. red brick at top. The foundation could be made without cut or ashlar blocks, using bricks and cement under the bedplate, and a chimney like this was built for $3,800, at Harrisburg, in 1872.

Mr. F. Firmstone had always thought brick chimneys were both better and cheaper than iron ones, but never supposed before that the difference in cost was so much in their favor. They had just finished the shell of a brick chimney at Glendon, 105 feet high and 6 feet in diameter, which would cost much less than the one described by Mr. Barnes.

This chimney rests on a concrete foundation 15 feet 6 inches in diameter. The base is 13 feet in diameter, 9 feet high, and 4 bricks (3 feet) thick. At 9 feet high, it is diminished by offsets to 11 feet 6 inches diameter, and $2\frac{1}{2}$ bricks (1 foot $10\frac{1}{2}$ inches) thick. Above this it is built with a batter of one-quarter inch per foot to the top, diminishing in thickness by three internal offsets, each of half a brick to one brick (9 inches) in the top section. A double row of hoop iron, in pieces about 2 feet long, was laid in the bed joints at every eighth course, one row close to the outside, and one close to the inside of the shell. It is to be lined to a height of 69 feet, with firebrick $4\frac{1}{2}$ inches thick. It was begun August 17, 1875, and finished October 8, in 44 working days, by 2 bricklayers and 5 laborers.

The cost, exclusive of scaffolding* and mortar, of which no account was kept, has been as below.

58,400 bricks at $10·25 per M. . . .	$598 60
2 bricklayers 44 days at $3 each . .	264 00
5 laborers 44 days at $1.10 . . .	242 00
10 bundles hoop iron	35 00
Cast iron cap, 2,280 lb. at 4 ½ c. . .	102 60
	$1,242 20

Suez Canal.—The filling up of the Suez Canal is an event that may now be considered indefinitely postponed. Last year between the two seas, only 52,700 cubic metres of "stuff" were removed, and the canal was navigated with facility by steamers drawing as much as 27 ft., and over 400 ft. in length. The bed of salt which forms the bottom of the Bitter Lakes, is gradually dissolving, so that this portion of the canal is being gradually but steadily improved, and with the increase of vegetation along the banks of the canal, there is a prospect of the production, in a not distant future, of a fertile and populous tract of country out of a sandy waste.

* Note by the Editor F. I. J.—In the construction of this chimney there was not only no necessity for a scaffold, but skilled chimney builders would prefer to work without one.

THE STRENGTH OF BOILER FLUES.

By Prof. W. C. Unwin.

[From London *Engineering*, July 7, 1876.]

Sir.—The strength of boiler flues is a subject of sufficient importance to deserve further attention. Putting on one side at present the formula of Love, there are three formulæ under discussion :

1. Fairbairn's original formula,

$$p = 806{,}300 \frac{t^{2.19}}{l\,d} \quad . \quad . \quad . \quad . \quad (1)$$

2. An approximate formula given by Fairbairn in a foot-note, which you term the practical form of Fairbairn's rule,

$$p = 806{,}300 \frac{t^2}{l\,d} \quad . \quad . \quad . \quad . \quad (2)$$

3. The same formula with a new coefficient deduced from the experiments by yourself:

$$p = 465{,}314 \frac{t^2}{l\,d} \quad . \quad . \quad . \quad . \quad (3)$$

You do not question, and it is certainly true that Fairbairn's original formula fits his experiments better than any other. But you think it must be abandoned (1) because it is too complicated and difficult to use, (2) because by adopting equation (3) the tendency to use thick plates is discouraged. The first objection may be removed by using a small table of values of $t^{2.19}$ calculated for those thicknesses of plate which are common in practice. The following is such a Table, and with its aid the collapsing pressure can be obtained as easily as the breaking weight of a bar :

t =	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$
$t^{2.19}$ =	·002307	·01053	·02558	·04803	·07829	·1167
t =	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	1
$t^{2.19}$ =	·1636	·2192	·2837	·3573	·5326	1·000

As to the second objection it does not seem to me well to mix up in one formula two entirely distinct classes of considerations. Fairbairn's formula is understood to give the collapsing pressure of flues uninjured by fire. If it is modified it will not give the collapsing pressure accurately, and it will not insure us against the danger of using plates of too great thickness, for it does not prohibit the use of plates of absurdly great thickness. No doubt thick plates are

dangerous, and the practical experience which leads us to avoid their use is best embodied in a separate cautionary rule.

In order that it may be seen in what degree the three rules differ, the following Table has been computed. Any of the numbers in this Table multiplied by $\frac{806,300}{l\,d}$ gives the collapsing pressure of a flue. The numbers in Column I are proportional to the collapsing pressure by equation (1). Those in Column II to the collapsing pressure by rule (2), and those in Column III to the collapsing pressure by rule (3). The Table extends to all the thicknesses likely to occur in practice.

	I	II	III
t	$t^{2.10}$	t^2	$a\,t^2$
$\frac{1}{16}$	·00231	·00390	·00225
$\frac{1}{8}$	·01053	·01563	·00902
$\frac{3}{16}$	·02558	·03515	·02029
$\frac{1}{4}$	·0480	·0625	·03606
$\frac{5}{16}$	·0783	·0977	·0563
$\frac{3}{8}$	·1167	·1406	·0812
$\frac{7}{16}$	·1636	·1914	·1104
$\frac{1}{2}$	·2192	·2500	·1443
$\frac{9}{16}$	·2836	·3164	·1826
$\frac{5}{8}$	·3573	·3906	·2254
$\frac{3}{4}$	·5326	·5625	·3246
1	1·0000	1·0000	·5771

Taking Fairbairn's rule as the standard equation (2) gives collapsing pressures 70 per cent. too high for tubes $\frac{1}{16}$ in. thick; 20 per cent. too high for $\frac{3}{8}$ in. tubes; and the error diminishes with the increase of thickness up to 1 in.; it then changes sign. Equation (3) gives collapsing pressures nearly right for very thin tubes, but the error for tubes $\frac{3}{8}$ in. thick is 30 per cent., and for tubes 1 in. thick is 42 per cent. The three rules differ so widely that it is not indifferent which is chosen. But if the experiments are relied on, there is no doubt that Fairbairn's original rule is the best. For moderately thick tubes rule (2) is not far from accuracy. For thin tubes, on the other hand, rule (3) is better than (2).

In applying Fairbairn's rule two points should be kept in mind. 1. In all Fairbairn's experiments, with, I think, one exception, there

was a longitudinal tension in the tube due to the mode of fixing, and it is possible that this to some extent influenced the results. 2. Fairbairn's tubes were so riveted and soldered that they were nearly as strong to resist compression at the joints as in the solid tube. This is not always the case with boiler flues. If the longitudinal seams, for instance, have lap joints they will probably give way in certain cases by shearing the rivets. In those cases no doubt the resistance will be altered.

Mr. Wilson has given a calculation of the direct crushing resistance of the tubes, and a similar rule is adopted by the Board of Trade. Without questioning that such a rule may have use as a counsel of caution, it may be pointed out that it is scientifically very defective on these grounds. 1. It ignores the influence of the ends. 2. It ignores the effect of the longitudinal joints. 3. It rests on a very doubtful estimate of the crushing resistance of iron.

The rule really gives the crushing resistance of an infinitely long tube, supposing that in such a tube buckling or collapse could not be prevented. There is no good reason for supposing that the influence of the ends ceases for short tubes, but *a priori* it might be expected that the influence of the ends was greater for short tubes than for moderately long ones. To take an extreme case, a tube 1 in. long must be so completely sustained by the ends that it is difficult to see how fracture could occur. Then if there are riveted joints, it is the crushing resistance of those joints, and not that of the solid plate, which should enter into the calculation. Lastly, Mr. Wilson takes the crushing resistance of wrought iron at 12 tons per square inch, and you have quoted from Rankine 36,000 lb. to 40,000 lb. as the crushing resistance. None of these numbers are very reliable. I have frequently loaded prisms of wrought iron, $1\frac{1}{2}$ diameters in length, with 50, 80, and even 100 tons per square inch. With such pressures the iron is much compressed, but often it is not cracked, and would carry a still greater load. Without, however, adopting these extreme numbers, it would be better to base the calculation on the elastic compressive resistance of wrought iron, which is known to be about 10 tons per square inch, and not on the very imperfectly known ultimate resistance to crushing. There is no reason why, with a passive kind of load, the working stress on a welded flue should not be 5 tons, and that on a lap riveted flue 2 tons or $2\frac{1}{2}$ tons per square inch.

The most remarkable feature of Fairbairn's experiments is undoubtedly the influence of the length on the resistance, and I do not know that any explanation of this singular law has been suggested. There is, however, one coincidence in the experiments which may afford a clue to the reason why the length influences the resistance. If the figures of the collapsed tubes are examined, it will be seen that at the moment of giving way they must have been buckled into a wavy form consisting of curved arcs meeting at points of contrary flexure. They form in fact a series of convex and concave bellies. Now the number of these bellies is related to the ratio of the length to the diameter of the tubes, as the following Table will show. This Table contains the whole of the experiments.

Ratio of Length to Diameter.	Number of Curved Arcs at moment of Collapse.	Ratio of Length to Diameter.	Number of Curved Arcs at moment of collapse.
15	4	5·0	6
15	4	5·0	6
10	4	4·75	6
9·8	4	4·75	6
9·5	4	4·8	6
7·5	4	4·8	6
7·5	4	4·0	4 } *
7·5	4	4·0	4 } *
5·0	4	3·75	8
5·0	4	3·7	8
5·0	6	3·7	8
5·0	6	3·2	4†
5·0	6	3·0	10
5·0	6	2·5	8

The least possible number of arcs into which the tube can divide is 4, and the number of arcs must be even. Looking at this Table the correspondence between the number of arcs into which the tube divides and the ratio of length to diameter is unmistakable. Connecting this with the known laws of resistance of a long column to longitudinal compression, it is not difficult to see a reason why the shorter tubes, which divide into a greater number of arcs, should have a greater resistance.

If we take a circumferential strip of the flue and treat it as a long column subjected to compression, then the external uniform

* Thick tubes imperfectly collapsed; lap and butt joint.

† Thick tubes slightly collapsed.

pressure p which would produce the waved form is given by the equation

$$p = \frac{1}{6} \frac{E n^2 t^3}{d^3}$$

where n is the number of arcs of which the waved form is made up. If, then, we can connect n with the diameter, length, and thickness, a partial explanation of the influence of the length would be found.

NOTE BY THE EDITOR F. I. J.—A discussion upon the subject of the law of strength of boiler flues under external pressure, has been carried on in *Engineering* since March last (having proceeded originally from a paper of Mr. Fletcher, the chief engineer of the Manchester Steam Users' Association, read before the Institution of Mechanical Engineers), while the discussion itself has been participated in by Prof. Unwin, as quoted above, by Robt. Wilson, C.E., and by the editor of *Engineering*, with others. To the pages of this valuable paper readers are referred for a full comprehension of the points in issue, with only a few remarks in support of Prof. Unwin's view of the case.

Sir William Fairbairn instituted a very elaborate series of experiments in pursuit of this law, which is published in extended form in his "Useful Information for Engineers." In the course of these experiments he observed with great care the effect of pressure under variations of length of tubes of a given diameter and thickness. Like all experiments with material not perfectly homogeneous, the results were somewhat divergent, but he obtained nineteen experimental examples which were to him satisfactory for giving an average result. He next followed the investigation by tests of tubes of larger diameter and of greater thickness. These tubes were not only open to the same unreliability of result, from imperfection of material, but they were no longer tubes, being riveted flues instead; yet, with the well-known acumen and the mechanical experience of Sir William Fairbairn, it would be difficult for any one to question his judgment in accepting certain values which he actually found in these trials, and in rejecting others. Thus, if his mature consideration led him, with all the conditions of the study fresh in his mind, to adopt experiments 24, 33 and 22 as representing with fairness the best approximation of a flue made from plates to a perfectly cylindrical flue, then

the acceptance of his conclusion will follow in the minds of those who can perceive no defect in the experimental data itself. After getting the data, however, the steps of reduction to rule which may follow are open to question. The extension of the table given by Prof. Unwin above the thickness of $\frac{1}{4}$ an inch is certainly unwarranted. There is no safety in estimated values passing the limits of observation in either direction. Within these limits the experimental errors are definitely established; beyond them, the effect of such errors cannot be anticipated; with small departure beyond limits no serious error can occur; but the attempt to extend a table which is extraordinarily cumulative between 0 and $\frac{1}{4}$ of an inch of thickness to 1 inch, will not give reliable figures.

Fairbairn's resulting empirical formula has the shape of:— $p = A \frac{t^{2.19}}{l\,d}$, where p = ex. pressure in pounds, t = thickness of tube in inches, d = diameter in inches, l = length in feet, and A = a numerical co-efficient determined by the experiments. It is a fair sequence to his experiments on tubes of a given diameter and thickness, that the pressure for collapsing, varied in inverse ratio with the length, but it would seem probable that the variation of pressure for tubes of other diameters and length should have been found to have followed some ratio of the thickness to the diameter, and not inversely as the diameter only. This fact is recognized by Sir Wm. Fairbairn in the attempt to reconcile the divergency for tubes of 12 inch diameter to the general law, although his attribution for reason of discrepancy "to the difficulty of maintaining such thin tubes of large diameter exactly in cylindrical form," cannot be taken as a full statement of the conditions which call for a correction in the form of $- B \frac{d}{t}$ to the general formula. At first sight it would look as if the form $p = A \frac{1}{l} \left(\frac{t^n}{d^m}\right)$ would have been more likely to give the approximate empirical formula, which should have covered a *further extended course of experiments*, and embraced the results with greater completeness. Prof. Unwin's observation, however, that a probable nodal condition accompanied the collapsing (under any ascertained load p), is warranted by the experimental data given by Fairbairn, and is a proper legitimate conclusion based upon materials of supposable homogeneity, and would appear in that formula which would

express the complete solution of the problem. Whatever formula should be adopted, as Prof. Unwin remarks, a table based upon it for practical use will divest the source of the table from any inconvenience, and possess the merit of correctness not belonging to an erroneous though simple rule.

Unfortunately, Fairbairn's experiments refer to a tube whose failure can only occur by passing the limits of crushing strength (which Prof. Unwin properly states, for wrought iron, to be 80 or even 100 tons per square inch), or by want of uniformity of the material; and his results are finally based on the average imperfection of his tubes in this last particular. While the requirement of the engineer is to know what are the limits of strength of flues made from plates riveted up, and subjected at once to the strains of their setting in the boiler, and to external pressure. Further experiments are clearly desirable, in place of arguing as to the construction of Fairbairn's formula with reference to its misapplication to boiler flues.

THE MANUFACTURE OF STEEL AND MODE OF WORKING IT.

By D. Chernoff, Assistant Manager of the Abouchoff Cast Steel Works, near St. Petersburg. Translated by W. Anderson, M. Inst. C.E.

Communication to the Russian Technical Society, 1868.

[From *The Engineer*, July 7th, 1876.]

Steel, as generally used in the arts, is a combination of iron and carbon. The purer these elements in steel, the higher are its qualities. The best steel that has ever been made in any age or country is, without question, "boulat" (the sabre steel of the Tartars). The special qualities of boulat, and especially the markings appearing on its surface, have sent many investigators on a wrong scent; all thought to find the extraordinary qualities of this steel in some special mixture. Careful analyses have been made, but, to the surprise of all, nothing has been found competent to explain the presence of the characteristic veining. Inasmuch as the veining of boulat is closely connected with its quality, it was attempted to find substances which, being melted with the steel, would produce the markings required. Steel was melted with various metals, with platinum, silver,

and so on, and veinings were, no doubt, produced; but in the first place, they were far from having the same regularity and beauty, and secondly, as well as chiefly, the steel produced was always inferior to boulat. The peculiarity of the veining of boulat lies also in this, that if you heat a good specimen of the steel with clearly marked veining to a bright red heat, and then allow it to cool, it will be impossible to restore the markings, no matter how long you treat the surfaces with acid. The veining, on the other hand, produced by the mixture of metals never disappears, however much the steel may be heated. But if the piece of boulat, in which the veining has disappeared, be melted again, then, if certain conditions in the cooling of the ingot are observed, the veining appears again, though of a somewhat different design; and in this manner it is possible to produce or annihilate the pattern several times. The investigations of Anosoff have clearly shown that the problem is solved in the purity of the steel, and he has succeeded, as is well known, in producing the very highest qualities of Eastern boulat. On a former occasion I spoke of the observations I had made on the ribbons of dead tint observable on the surfaces of steel guns in the lathe. By means of careful daily records in the forging of the gun ingots, I found that these tints appeared in the boundaries between the hot and the cold portions of the ingot being forged; that is to say, always at those points up to which the ingot was pushed into the furnace. The position and appearance of the strips of dead tint always coincided with the position and form of the limit of heating. If a spot so noted by me was afterwards reheated, then the ribbon of dead tint no longer appeared after turning in the lathe. Besides this, some of these ribbons would disappear as a greater or less thickness of metal was turned off; others penetrated right through the mass of the gun, and never disappeared.

It is further remarkable that although, at times, the transition from the heated to the cold portion of the ingot was so gradual that it was impossible to assign any limit, yet the ribbon of dead tint developed by the turning of the surface of the gun, and corresponding to the above ill-defined limit of heating, was so clearly marked, that it was easy to trace its boundaries with a pencil on the surface of the gun. It must be remarked also that the ribbon has only one well-defined margin, that which was turned towards the cold end of the ingot; the other margin is shaded off imperceptibly into the

normal end of the steel. Wishing to investigate the effects of the steam hammer on the structure of steel, I heated a $4\frac{1}{2}$ inch ingot to a bright red color, and subjected it to two heavy blows of a 5 ton hammer, so that one-third the length was not touched at all, the second third was flattened to 3 in., and the last received two cross blows, under each of which there was a compression of at least $1\frac{1}{2}$ in. The ingot was then left to cool in the open air, and on being broken it was found that the appearance of the structure of each of the three sections remained identical, not only to the naked eye, but to the most careful microscopical examinations.

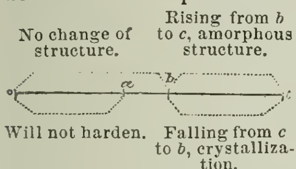
I have also drawn attention to the circumstance that, on one occasion, when experimenting on the influence of the temperature to which steel was heated, on its hardness in tempering, I ordered a smith to heat a piece of steel to dull red, but he, by mistake, heated it bright red. Wishing to rectify the error, I did not at once plunge the steel into water, but let it first cool down to dull red, and then immersed it. Although the steel was of a quality capable of extreme hardness in tempering, the immersion not only did not make it hard, but actually made it sensibly softer. I have recalled the above circumstances, because in connection with many others, they induced me to investigate the influence of temperature on steel, and formed points of departure from my researches. Space will not allow of my describing my experiments in detail. I must content myself with stating the conclusions to which I have arrived. If steel melted in a crucible is constantly kept in violent agitation while cooling, agitation violent enough to keep all its particles in motion, then the cold ingot produced will have a very finely crystallized structure; if, on the other hand, the melted steel is allowed to cool in perfect quiet, then the resulting casting will consist of large, well-developed crystals. The appearance of these crystals, and generally the tendency to crystallize under these circumstances, will depend on the purity of the steel. As I have already stated, the ultimate purity of the steel consists in that of the two component elements, iron and carbon, and that the best steel is composed of only these two elements. With reference to other elements, the presence of which is supposed to influence the quality of steel, it is impossible to avoid mentioning the opinion of Fremy, who considers nitrogen so essential, not only to the formation, but to the very existence of steel, that he has laid down the proposi-

tion that "if nitrogen is taken away from steel it will cease to be steel"—*Comptes Rendus*, vol. lii., April, 1861; and the supporters of this theory, who go further, and affirm that steel is a union of iron with cyanogen, which can even be seen burning with a violent flame during the process of casting steel. However, up to the present time—1868—the most careful researches of Caron, Marchand, Biot, Bousingault, Rammelsberg, and others, have not confirmed the assertions of Fremy; for, on the one hand, nitrogen is found also in soft wrought iron and in cast iron, and on the other, the quantity of nitrogen found in steel is very variable, and bearing no fixed relation to the quantity of carbon; and furthermore, it exists in such small quantities as to be less than a tenth part of the carbon. For instance, Busengoll found 0·00057 part of nitrogen in cast steel, and 0·00124 part in soft wrought iron.—*Comptes Rendus*, vol. lii., p. 1251. On another occasion, he found in Krupp steel 0·00022 part of nitrogen, and in soft wrought iron and in cast steel, 0·00007 part each.—*Comptes Rendus*, vol. liii., p. 9.

With reference to the influence of different metals on the quality of steel, it is necessary to state that some of them communicate a particular color, some diminish the tendency to rust, and others displacing the carbon, enable the steel to acquire very great hardness in tempering, and so on; but the greater number of substances combined with steel, even in its most insignificant proportions, very considerably lower its quality. For example, the malleability of steel being in direct relation to the quantity of carbon contained in it, is materially lowered by the presence of foreign substances. Bessemer steel No. 1, containing 2 per cent. of carbon, is hardly malleable—Boman, *Das Bessemern in Schweden*, 1864; whereas, according to Anosoff, pure steel retains its malleability with 3 per cent. of carbon, forming the hardest boulat. Speaking generally, all the efforts of metallurgists to obtain the highest qualities of steel should be directed to separating impurities from the raw materials, so that the produce of their operations should be a combination of iron and carbon; and all the specifics and nostrums forming the subjects of so-called secrets will be found to consist, in effect, not in the introduction of new materials, but in purifying the raw, and only, as a last expedient, driving out pernicious impurities by means of substances less harmful. It may as well be said that tungsten steel has not proved a dangerous rival to carbon steel. The fact is that tungsten, when

steel containing it is heated, gradually oxidizes, at first on the surface of the ingots, and then by degrees to the very centre, so that after a few heats the steel loses its peculiar qualities. This oxidation takes place even at ordinary temperatures.

As I have already stated, steel, cast and allowed to cool quietly, assumes a crystalline structure. If you heat such an ingot to a bright red heat, and allow it to cool without working it in any way, then on breaking the mass you will find that its structure has been altered. In order to explain the law regulating the change of structure produced by heating, I draw a line, on which, as on the scale of a thermometer, I shall mark certain points, corresponding to several determined temperatures.

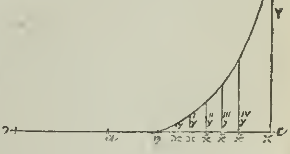


Let the point *o* be the zero of the thermometric scale: *a* marks the temperature of dark cherry-red; *b* red, but not sparkling; and *c* the melting point of a given sample of steel. The points *a*, *b*, and *c* have no permanent place on the scale, but vary with the quality of the steel (in pure steel this variation depends directly on the quantity of carbon contained); the harder the steel the nearer these points move to *o*, and the softer the steel the further off, and, speaking generally, with varying rates. The limits of these movements are sufficiently narrow, so that an inexperienced eye would hardly discern them. Not having suitable apparatus for measuring the temperatures, I have been compelled to denote them by the colors exhibited in heating, the various shades of which only an experienced eye can appreciate; and it must be added, that the colors named have reference only to hard and medium qualities of steel; for in the very soft kinds, nearly approaching to wrought iron, the points *a* and *b* recede very far, so that, for example, in wrought iron the point *b* corresponds to white heat.

The definition of the point *a* is as follows:—Steel, however hard it may be, will not harden if heated to a temperature lower than *a*, however quickly it is cooled; on the contrary, it will get sensibly softer and more easily worked with the file. Not having time to enter into the explanation of this phenomenon, I will refer to the investigation of Jullien (*Les affinités capillaires et les phénomènes de la trempe mis en présence*, Paris, 1866) on tempering in general, from which he deduces the very probable conclusion that steel, in cooling

from a red heat, appropriates a certain amount of latent heat, the quantity of which is directly dependent on the rate of cooling; so that the quicker the steel is cooled the greater quantity of latent heat it will contain; but if the rate of cooling diminishes below a certain limit, then the latent heat all escapes, and no hardening can take place. The actual hardening Jullien explains by the supposition that the carbon assumes an abnormal crystalline condition. I will add from myself that all this takes place only when steel is heated above the point marked *a* on our scale. The definition of the point *b* is that steel, heated to a lower temperature than *b*, does not change its structure, whether cooled quickly or slowly. This expression, however, must be taken conditionally, because steel, during long periods of time, and especially under the influence of shocks or vibrations, and at ordinary temperatures, but to a less extent than wrought iron changes from the finely granular to a coarse crystalline structure; and as regards the heated, and therefore softened, condition, and especially at temperatures approximating to that indicated by the point *b*, it is probable that with the greater facility of motion, the change of structure will take place more rapidly. In my own experiments I have kept pieces of steel at temperatures near to *b* for about eight hours, but after cooling slowly in hot sand, I have been unable to detect any change of structure. As soon as the temperature has reached the point *b*, the substance of steel quickly passes from the granular (or, speaking generally, crystalline) condition to the amorphous (wax-like structure), which it retains up to its melting point, that is, to the point *c*. In this condition steel possesses the property of incompressibility, and, at the same time (with respect to the permanence of the amorphism), has an analogy to an exceedingly concentrated solution of a strongly crystalline salt. To make my meaning clearer, imagine a piece of crystallized alum put into a beaker and carefully heated. On attaining a certain determined temperature the piece of alum will appear as if damp, the separate crystals forming the mass will seem, as it were, to be sticking or clinging to each other, forming a mass on the point of melting, and which actually gradually becomes fluid, and forms a solution of the crystals of alum in their own water of crystallization. Now if this fluid mass is allowed to cool, it will again crystallize, and according to the conditions under which this cooling takes place we can obtain any quality of crystals, from the coarsest to grains so fine as to be scarcely per-

ceptible to the naked eye. If the fluid is allowed to cool very slowly, and in perfect quiet, then large regular-shaped, well-developed crystals will be formed; but if, with the same gradual cooling, the liquid is kept in constant agitation (shaken up), the crystals will come out very small. Allowed to cool quietly but rapidly, the crystals will also be small; and, finally, the least favorable condition for crystallization is when the liquid cools rapidly, and is at the same time violently agitated. In a word, all depends upon the greater or less *time* and the greater or less freedom of motion the particles possess among themselves for collection into crystals; the first condition depends upon the rate of cooling, the second, upon quiet and the greater or less density (thickness) of the mass undergoing crystallization. The same changes take place in the structure of steel heat above the point *b*. The higher steel is heated the softer it becomes, the greater, therefore, is the liberty its particles pcssess to group themselves into crystals, if the quiet of the mass is not disturbed by extraneous forces; and the slower the temperature is suffered to fall to the point *b* the more time they have for the purpose. At temperatures lower than *b*, as already stated, the structure of the mass does not alter. In this case the action of carbon on iron may be likened to that of water of crystallization on its salt; that is, it may be supposed that carbon at the temperature *b* begins to dissolve iron just like the water of crystallization at certain temperatures commences to dissolve the solid substance of the salt. This hypothesis receives confirmation in the process of cementation, in which the iron must be heated to above a certain temperature or no effect will be produced, no matter how long the bars remain in contact with the carbon; it is very probable that the temperature at which carbon begins to be absorbed in cementation is very near to the point *b*.



The power of steel to become granular may be graphically illustrated thus:—On our scale of temperatures *o*, *a*, *b*, *c*, a curved line rises from the point *b*, and the ordinates *y y*, &c., of this curve represent the degree of development of the grains for the corresponding temperatures *x x x*, which become the abscissæ, but necessarily under similar conditions of cooling from the several temperatures *x x* to the temperature *b*. At some temperature X lower than the melting point C, the ordinate

Y becomes infinite, and an asymptote to the curve, the practical significance of which is apparent in the well known fact that steel will not endure a high welding heat, but falls to pieces in the fire; and the harder the steel the lower is the temperature at which this takes place, and, therefore, the nearer is the temperature X to *o*, and the further from C.

In manufacturing articles of steel we try to get them as much as possible of a fine grained structure, especially if strength or toughness is the first object sought. I say that it is better to obtain steel of a finely crystalline structure, because numerous experiments have demonstrated that the greater the preponderance of the crystalline formation, the larger and more regular the crystals are in a given piece of steel, the less resistance does it offer to fracture, the less tenacity does it possess, and, therefore, men connected practically with the working of steel recognize its qualities by the appearance of its fracture. If the fracture is fine-grained, they say the steel is well forged and consolidated; if it is coarse-grained, it is badly forged and of an open character.

Although we are in the habit of associating with the forging of steel an idea of increased density, yet, in reality, it appears that, in most cases, forging only changes the form of the steel, and, according to the relations between the force of the blows and the thickness of the piece of steel being worked, hinders crystallization of the mass to a greater or less degree, but does not increase its density—I am speaking only of forging above the temperature *b*, such as is general in working large ingots. The force of the blows is too small to vanquish that gigantic molecular force of heat that keeps the particles of steel at a definite distance one from the other. The problem of forging—at temperatures higher than *b*—consists in this, that while changing the form of the mass of steel, it should have no time to cool and crystallize quietly, but should be kept in the amorphous condition till such time as the temperature sinks below the point *b*, after which, if left to cool in quiet, the mass will no longer crystallize, but will possess great tenacity and homogeneity of structure, so that it will oppose in all its parts a uniform resistance to external forces, of course supposing the chemical composition of the mass throughout to be the same. But if the problem of forging was limited to the above conditions, it is easily seen, that working steel under the hammer might be dispensed with, and the required form given at once by

casting in suitable moulds, and preventing crystallization by rapid cooling. In reality, however, things are very different. The difficulty of forging is aggravated by the circumstance that the cast ingots out of which guns, for example, have to be made, are full of pores, filled with gas, bubbles penetrating the interior as well as the surface of the mass, and also with scales and cracks due to contraction, so that, as the castings are delivered from the foundry, it would be impossible to make use of them. These bubbles and cracks must be squeezed or pressed together, and this can only be done by powerful mechanical means—by heavy forging. Simply unforged cast steel is neither less dense, nor less strong than steel of the same molecular structure, and forged at temperatures higher than *b*. To convince myself of this, I made a number of experiments, first on the density of the two kinds of steel, and found that in most cases forging had diminished the specific gravity; and, secondly, I found, that the tenacity of the cast steel was in nowise less than that of the forged, provided, as I said before, both have the same structure. To prove this, I took a cast ingot of coarse crystalline structure. I had it cut longitudinally into four parts. One of these parts was turned down in the lathe, and tested in the proving machine. The second piece was heated to bright red, and vigorously forged under a 3-ton hammer, the forging being stopped when the temperature fell to very nearly the point *b*; the specimen was then turned down, and also tested in the proving machine. The third piece was made red-hot, very nearly the same temperature at which the forging of the second piece terminated, and was allowed to cool in the open air, without being forged. Having broken a small piece off this last specimen, I found that it had assumed a finely granular structure, very similar to that of the second forged specimen. The third sample was also turned down in the lathe and tested. The three specimens are now before you, and you may judge for yourselves what varieties of structure the self same piece of steel may be made to assume. The results of the experiments are given in the following table.

I must also remark that on the fractured surface of the third sample, as you may observe for yourselves, there is a spot of iron occupying about one-sixth of the area, and which was undoubtedly the cause of premature fracture, for the appearance of the fracture clearly shows that it began at that spot. In order to establish the propositions I have advanced, it will, of course, be necessary to institute a

complete series of experiments.* As regards trials by bending and breaking under the hammer, an immense number of experiments have convinced me of the correctness of my views.

	Ultimate Strength, in tons per sq. inch.	Ultimate extension.	Diameter of specimen—inch.	Dynamic resistance per cubic inch in inch tons. Ultimate Strength × ½ elongation.
1st. Unforged specimen	34·8	0·023	0·885	0·8
2d. Vigorously forged specimen	41·5	0·053	0·85	1·1
3d. Not forged, but made finely granular by heating	38·7	0·166	0·63	3·21

[To be continued.]

A MODERN ORGAN.*

[From *Nature*, July 27th, 1876.]

It has been hitherto chiefly on the Continent of Europe that connoisseurs in the majestic tones of the king of instruments have had to seek for a grand organ. Though London, the mistress of the world for wealth and magnitude, has churches and chapels innumerable, and organs by hundreds, scarcely one is of sufficient importance or merit to attract the attention of a stranger. Church organs are, as a rule, small, and built without individuality or character of tone, and generally so placed in the building as to effectually mar in acoustical effect any special merit they might otherwise possess. Of the two or three instruments that have any pretensions to magnitude to which the public has access—at the Albert Hall and the Alexandra, and Crystal Palaces, no very lasting impression remains upon the audience beyond that of noise and a distressingly harsh volume of sound, utterly devoid of musical depth and grandeur of tone, and quite different from the pleasing reminiscences that dwell upon the memory from hearing some of their more musical Continental Rivals at Haarlem, Freiburg, or Lucerne. To successfully construct a large organ is a work of exceeding difficulty, for not only does size greatly complicate the mechanical action, but the proper distribution and appor-

* 1875. Since the above was written, numerous experiments at the Abouchoff Works have fully demonstrated the truth of my views.

tionment of the wind to each stop, and the harmonious blending of the whole together in the full organ, demands great knowledge and skill upon the part of the builder. It is for these reasons that very few large organs rise beyond mediocrity, or are noted for the beauty of their tone or the perfection of their mechanism. The great advance in the general taste for organ music within the last few years has necessitated an improvement in the mechanical construction of the organ, so as to enable the performer rapidly to command the entire resources of the instrument at will, and give him absolute control over the various sound-combinations and tone coloring of the different stops, according as they are brought on or off, by means of the appliances placed at his disposal.

We give a brief description of the very remarkable organ recently erected at Primrose Hill Road, Regent's Park, remarkable alike for its size, being larger than the great Haarlem organ, its beauty, richness, and grandeur of tone, and the completeness of its mechanism. At present this superb instrument is almost entirely unknown to the musical section of the public. It possesses what is known as a 32-feet metal speaking front, with a corresponding weight of tone throughout the pedal organ, and its several organs, which together constitute the instrument, give it a conspicuous place in the scale of magnitude as compared with the more celebrated of the continental instruments. The instrument in question has many novelties not to be found in other organs. It possesses seven distinct organs: pedal, great, choir, swell, solo, echo, and carillon organs, each extending the full compass of 5 octaves (61 notes) with the exception of pedal organ, 30 notes. These various organs are under the control of the performer by means of four manual key-boards, which together comprise sixty-seven speaking-registers, and these are combined together with various acoustical effects by means of thirty-one mechanical movements, making a grand total of ninety-eight sound-controlling registers, worked by hand and foot. The entire mechanical action necessary to control these registers and accessory movements is carried out by a novel application of atmospheric vacuum pressure. Two distinct *systems* of main air trunks extend throughout the interior of the organ, in connection with the wind arrangements situated in the basement of the building. One of these *systems* of trunks is for the purpose of conveying the wind at different pressures to the sound boards of the various organs in affecting the musical speech of the several groups of pipes. Thus

the wind supplied to the solo organ, swell reeds, and large pedal reeds, is the heaviest pressure employed in the instrument for producing the musical intonation of the pipes, namely, 6 inches. The wind pressure to the sound-boards of the great organ and swell flue work is 4 inches, that of the choir organ 2 inches, and the pressure of wind is again reduced in connection with the sound-boards of the echo organ to half an inch, the lightest wind upon which any organ has ever yet been attempted to be voiced. This question of wind pressure as affecting the voicing and musical intonation of the pipes of an organ is one of great importance, and upon the skilful adjustment to the size, diameter, and materials of which the pipes are constructed, depends the sweetness and quality of the musical tones produced. In the organ under notice the very light pressure of wind adopted, affords an example for careful study and examination. First, for the mellow sweetness and beauty of tone produced; secondly, for the promptness of speech obtained, as rapid as the articulation of a pianoforte string; and thirdly, for the immense volume of sound and power that can be produced from these light pressures, the combined effect of the full organ rivaling almost the artillery of heaven as thunder, crash after crash bursts upon the ear. Much of the harsh unmusical tone of modern organs arises from this desire to obtain power at the expense of music by the employment of an over-pressure of wind. That age is not requisite to mellow an organ is demonstrated by listening to the diapasons and foundation stops of the Primrose Hill organ, which have all that ripe and fascinating sweetness of tone characteristic of Silbermann's finest instruments. These light pressures of wind constitute a remarkable feature in the construction of so large an organ.

The second series of air trunks which permeate the interior of the instrument are in connection with two large vacuum exhaust bellows which, being continually actuated by the steam-engine used for blowing, maintain a constant vacuum pressure throughout the entire system of trunks, so that at any part of the organ an available mechanical power (that of the pressure of the atmosphere 15 lbs. to the square inch of surface) is at hand to be employed for the multitude of purposes required in a large instrument. To be obliged to have recourse to the old system of wooden rods, trackers, levers, and squares in endless complications, would have so weighted and impeded the action of the organ as greatly to destroy its musical capabilities.

In most of the large organs constructed both at home and abroad, many parts of the mechanism are far from being easy in action and the performer upon the instrument rarely is able to portray with desirable rapidity, his musical creations mechanically at his finger-ends as those creations in tone-color may come to his mind. By the introduction of atmospheric vacuum pressure as the "motor" power, there is no complication of mechanical parts; an almost endless system of tubes being carried from the key-board registers to the sound-board sliders of the several organs. These tubes are in connection with powerful exhaust and vacuum power-bellows attached to the sliders, so that any required stop is brought on or off instantaneously, however distant from the key-board. These tubes may be bent and twisted round corners in any direction, and the parts of the organ most difficult of access easily reached. No mechanical force is therefore necessary to be exerted at the key-boards, the mere touch of a key, register, pedal, or finger-button, at once brings its special tube and exhaust arrangement into operation. The wonderful completeness of this system of vacuum-tube action is beautifully illustrated by means of the echo organ—a complete instrument of 16 feet tone, situated some 100 feet from the key-boards of the great organ—and supported on corbels against an opposite wall at an elevation of some 30 feet from the floor. The action of this echo organ is accomplished by means of electric force combined with the system of vacuum tubes; there is no mechanical communication between the performer at the key-board 100 feet distant and the organ pallets which admit the wind to the pipes, save a small rope of 61 insulated copper wires—one wire for each note of the five octaves. The various stops of the distant organ are likewise controlled without mechanism—a series of vacuum tubes alone extending from the registers at the great organ to the sliders of the echo organ—which are thus brought on or off at the will of the performer by a silent action—at once accurate and instantaneous in its manipulation. The effect of this echo organ, is that of a large organ heard at a great distance. Without the aid of the electric action and vacuum pressure, such an organ could not have been designed. Mechanical action would never have successfully developed such effects at such an extended distance.

The same vacuum system is also applied to the various pneumatic lever arrangements interposed between the keys at the consol and the

wind-valves at the sound-boards to relieve the performer from any undue mechanical pressure that might detract from the promptness of repetition and delicacy of touch of the key action, the key-boards being thus rendered as light as that of a grand pianoforte. Such results cannot be obtained so efficiently by the employment of compressed air for a pneumatic power action; compressed air will always prove to be more or less sluggish, a "creeping on" and "creeping off" movement being the result, besides a limit to the aggregate of the instantaneous power that is at command.

The pneumatic drawstop action of the St. George's Hall organ, Liverpool, is a fair illustration of the defects of the compressed air system. In the Primrose Hill organ upwards of forty registers can be simultaneously drawn on or shut off as easily and with the same precision as though only a single stop were drawn. The consol or key-boards of this organ are reversed, that is, the performer faces the audience, the organ being behind, and the echo organ opposite him. The lowest key-board manual is the "great organ;" the next, or second from the bottom, the "choir organ;" the third in the series the "swell organ;" and the fourth, or upper row of keys, the "solo organ." By a simple mechanical arrangement this fourth key-board is also used for the electric "echo organ," and also for the carillon, or "bell" organ, otherwise it would have been necessary to have introduced a fifth set of keys, an arrangement at all times objectionable from the increased complications imposed upon the performer. The touch of the carillon organ on the fourth row of keys is expressive like that of the pianoforte key, and gradations of tone and distance are therefore capable of being expressed upon the bells.

In this organ the French ventil system of shutting off or bringing on the wind to a complete family or group of stops by the depression of a pedal has not been adopted, such a system being found inadequate to effect rapidly the almost endless combinations that such a large instrument has at command, the pneumatic combination foot pedals and finger buttons at the key-boards being introduced as a more convenient form of manipulating the registers.

The wind supply of this gigantic organ is furnished from four large reservoirs in the basement, which again supply seventeen reservoirs in connection with the various sound-boards of the organ; the vertical feeders for producing the wind to these reservoirs, as well as for creating the vacuum pressure, are set in motion by an eleven horse-

power steam-engine. The wind supply is so ample, that with the power of the full organ it is impossible to exhaust or create unsteadiness in the wind; few organs are properly constructed in this important respect. An ingenious automatic lever engine for regulating the motion and the supply of wind from the vertical feeders into the reservoirs according to the demand of the organ, is placed between the steam-engine and the wind reservoirs, so that the regulation of the wind supply is independent of the speed of the engine, which remains constant. This instrument, which stands 50 feet high, 30 feet broad, and 30 feet deep, occupied three years in construction, and was opened in January, 1876. It has been erected in the large music-room at the Hall, Primrose Hill Road, built expressly to receive it, under the personal supervision of Mr. W. T. Best, of Liverpool, by the eminent organ builders, Messrs. Bryceson Brothers, and Morten, of London, for Nath. J. Holmes.

A VISIT TO THE NEW VICTORIA DOCK WORKS AT EAST HAM.

[From *The Builder*, July 15, 1876.]

The London and St. Katharine's Dock Company are at present engaged in the construction of a very great extension of the Victoria Dock, the intended enlargement of the existing water area of the dock being upwards of 90 acres, in addition to further quay and warehouse space, having a frontage of nearly four miles in length, and covering an area of about 120 acres, the aggregate area of the enlarged dock and quay space being about 200 acres in extent.

The works are now in active progress, and the following particulars, obtained by a visit made last week to the spot, may be interesting.

The site upon which the new dock and quays are being constructed forms a portion of the Plaistow Marshes at East Ham, and stretches in an eastward direction from the boundary of the present dock to the northwest bank of the Thames, where the bank will be entered from the river at a point between North Woolwich and Barking Reach, and about a mile and a half below the first-named place. It is bounded on the north by Beckton and the gas-works, and on the south by North Woolwich. The entire length of the land on which the dock and quays are being formed, from the junction with the existing dock to the river bank, is upwards of two miles, situated partly in the parishes of East and West Ham and Plaistow, in the

county of Essex, and partly in that portion of North Woolwich which forms a part of the county of Kent.

The company obtained an Act of Parliament last year for the works in question, and there has been no delay in their commencement. A large area of land, several acres in extent, at Silvertown, and immediately adjoining the new dock site, presents a perfect village of workshops and huts, which have been erected by Messrs. Lucas & Aird, the contractors, for the purpose of carrying on the works. The excavations for the docks are being actively carried forward, upwards of 2,000 men being at work, and more than a score of locomotive engines, in addition to several excavating machines of American invention, which perform both the work of excavation and also that of conveying the excavated earthwork into the wagons drawn by the locomotives. The amount of excavation to be effected is something enormous, amounting to between 3,000,000 and 4,000,000 cubic yards, of which a large portion has already been executed; the excavated material forming an embankment on the north and south sides of the intended water area, and which will form the site for the quays, and the warehouses, and other buildings to be erected.

In carrying on the excavations some interesting geological discoveries have already been made. From the surface to a depth of several feet the earthwork consists of peat, and amongst it a number of fallen trees, in an admirable state of preservation, have been found. Underneath the peat a bed of gravel has been met with, and below this gravel a stratum of concreted shells and clay have been come upon, intermingled with which stag-antlers and other animal remains have been found.

The water area of the new dock will be 7,640 ft. in length, with a width at the water level of about 540 ft., covering, as already stated, upwards of 90 acres, and it will have a minimum depth of 27 ft. below Trinity high water. In addition to this area the entrance lock from the river into the dock will be 800 ft. long and 80 ft. wide, with strong and powerful gates, which will be opened and closed by hydraulic power.

The entire area of the Victoria Docks and quay space, when the works now in progress are completed, will be upwards of 300 acres, with a circumference of more than five miles.

The enlarged dock, when completed and joined with the present dock, will thus have two entrances, namely, the present entrance on

the west side at Blackwall, and the new entrance now in course of construction at the east end near Barking Reach, there being a river frontage of three miles and a half in length between the east and west entrances respectively.

Near the entrance lock to the enlarged dock below Woolwich, the Ham Hall and Woolwich Manor road intersects the land which will form the lock, and this road is intended to be diverted in the direction of the river, with the construction of a swing-bridge across the lock, to be opened on vessels entering and leaving the dock.

An important feature in the undertaking is the diversion and partial reconstruction of the North Woolwich branch of the Great Eastern Railway. This line runs immediately along the northeast side of the present Victoria Docks, intersecting a portion of the site upon which the enlarged dock is in course of construction, and in order to admit of the extended dock being connected with the existing dock, the North Woolwich line is to be diverted, and carried under the dock by a tunnel at a depth of 43 ft. below high-water mark.

The facing of the dock walls will be of granite, several feet in thickness, and in addition to the large quantity of stone which will be required, it is estimated that not less than 30,000 tons of Portland cement will be used in the construction of the works.

It is calculated that the new works, the estimated cost of which is nearly 1,000,000*l.*, will take about three years to complete. They have been designed by Mr. A. M. Rendel, C. E., of Great George street, Westminster, Mr. Anross being the resident engineer.

The magnitude of these works suggests a comparison between the area and extent of the London docks, and those on the banks of the Mersey, at Liverpool and Birkenhead. The estimated water area and quay space of the London and St. Katharine Docks are about 120 acres; the East India Import and Export Docks, 32 acres; West India Import and Export Docks, 54 acres; South Dock, 24 acres; Timber Dock, 21 acres; Commercial Docks, 150 acres; Grand Surrey Docks, 75 acres; and Victoria Dock, 90 acres (exclusive of enlargement in progress; being a total of 566 acres. The water area and quay space of the Liverpool docks are 259 acres, and that of the Birkenhead docks 166 acres, being a total of 425 acres on both sides of the Mersey, as compared with 566 acres, the present area of the docks on the Thames, exclusive of the Victoria dock extension now in progress.

GAS WORKS ENGINEERING.

By Robert Briggs, C.E.

[Continued from Vol. cii, page 104.]

"An exhauster is a pump, generally rotary, which is used to pump the gas against all pressure to which it may be subject between the hydraulic main and the holders. To state these pressures in reverse order, they are—first, those of the holder, which, with telescopic holders, is variable, and amounts to from three to five and a half inches of water column; second, those of the purifiers, varying but little from two and a half to three and a half inches for lime purifiers (with lime of usual quality and condition); third, those of the washer, condenser, pipes about the works, &c., grouped together, of perhaps one to one and a half inches; giving a total of six and a half, to ten and a half inches of water-pressure. Now it has been found that any increase of pressure on the retorts over the half-inch of seal for the main, occasions a peculiar destructive distillation (probably of the first formed hydro-carbons, and possibly those formed before the coal is well heated), whereby solid carbon deposits by accretion upon the inside of the retort, especially at the back end, and rapidly fills it up and impairs its heat-conducting and gas-forming powers; and hence it is requisite to suck the gas from the direction of the retort, and force it in the direction of the holder, until the retort is relieved from everything but the hydraulic seal pressure.

"As these total pressures vary in amount from time to time, and from hour to hour, and as the quantity to be pumped varies in the same way; the exhausters are driven by separate engines, regulated for the procurement of the pressure desired on the hydraulic main, and are always provided with steam-power enough to overcome the largest resistance, and to impel at the same time, the largest quantity of gas presenting itself to be moved. Experience has suggested, and ingenuity provides, all the safeguards for successful automatic accomplishment of the requirements here stated, and the exhauster has become one of the most reliable parts of a gas apparatus. The necessity of my allusion to this portion of the working machinery in its place of application in the Market street works will appear when noting the question of purification.

"There are, at the Market street works, three '*sets*' of purifying '*boxes*.' A set of purifiers is four in number, three of which only

are in regular use at any one time. The thirty-six inch main-pipe is brought into the purifying-house, where three branches of twenty or twenty-four inches diameter are taken from it, which branches are joined to, and form the main inlet-pipe of the '*centre-valve*' of each set; while, from the centre-valve, three main '*outlet pipes*' lead away, and convey off the *purified* gas, to another thirty-six inch main-pipe; and this last and final pipe of the gas-works goes to the great meters, and thence to the holders where the gas is stored.

"The centre-valve needs a brief description to be understood. It is a large cast-iron box, with numerous internal divisions, and it is three stories in height; to the bottom story, the main inlet and outlet pipes are joined; to the next story or '*body*,' four *pairs* of pipes connect, one pair going to each of the purifiers; while the upper story is a circular '*cover*,' which is loose, and can be turned on its axis.

"The cover fits gas-tight on the body, and has internal divisions corresponding (but not agreeing) to those of the body. The arrangement of the divisions is such, that if the cover be placed in a given marked position, the gas will now enter the main inlet-pipe, pass through one of a pair of purifier pipes and return again by its mate pipe to the centre-valve; then pass out of the centre-valve through one of the pair of next or second purifier pipes and return by *its* mate; and so to another or third purifier, and back again to the centre-valve; but now, in place of going to the fourth purifier, the gas will pass out of the centre-valve by the outlet main; thus the fourth purifier will have been shut off altogether. This same course of events will follow when the cover is turned a quarter of an entire rotation; only that the purifier before shut off will have become number one of the series, and the purifier before number one will have been shut off. The operation of the centre-valve may be otherwise described. Suppose a set of four purifiers are designated by the letters A, B, C, D. Now, the different positions of the centre-valve may be assumed to be as follows:

	First.	Second.	Third.	Out of use, shut off to be cleaned.
First position of centre-valve (cover),	A	B	C	D
Second position of centre-valve cover ($\frac{1}{4}$ turned), ...	B	C	D	A
Third position of centre-valve cover ($\frac{2}{4}$ turned), ...	C	D	A	B
Fourth position of centre-valve cover ($\frac{3}{4}$ turned), ...	D	A	B	C

"The next one-quarter turn of the cover will obviously restore *everything* to the first position; and, by this exposition it will be made evident that the gas, when passing through the three purifiers in operation, will have entered the one longest in use and escaped from the one most recently cleaned. Purifiers are made (for dry-lime purification) of the proper size, and with the proper dimension of pipe connection and centre-valve, to demand the cleaning of one of them each twenty-four hours.

"The purifiers at the Market street works are of the customary construction, that is, cast-iron '*boxes*' with wrought-iron '*covers;*' the covers having 'sides' (a rim projecting downwards) which drop into a '*cup*' or trough, partly filled with water, which cup surrounds the sides of the boxes; the '*seal*' thus made forms the gas-tight joint between the covers and the boxes.

"In this instance, the dimensions of any one of the purifiers are twenty-four feet square on the floor by three feet three inches deep, inside measurement. Inside of the boxes is placed seven layers or flats of perforated iron or wood movable '*screens*,' and upon these screens is spread damp slaked time in layers of two and one-half to three inches in thickness. [This damp slaked lime is called 'dry lime,' in contradistinction to thick liquid lime-water, which is called 'wet lime.'] The gas enters at the bottom of the first purifier-box, ascends, percolating through the seven layers, to the top; a pipe which passes down through the screens to the bottom, carries off the gas (through the centre-valve) to the second purifier; where the same operation follows; to the third with like result; and from the last it passes out, purified, ready for distribution to consumers.

"The lime used at the Market street works is oyster-shell lime; and, from the annual report of the Trust, I gather that there is used for every five thousand cubic feet of gas made very nearly one bushel of lime; and as the same authority shows (by estimate) the production of about 4·4 cubic feet of gas from each pound of coal, it follows from the six charges of two hundred pounds to a retort, that there are needed a little more (1·06) than a bushel of lime for each retort in service; and furthermore, as the works are planned for three hundred retorts for each set of purifiers, that three hundred and twenty bushels of lime will have been vitiated in the working of any one set; and finally, that nine hundred and sixty bushels of lime will be the maximum daily demand.

"The manipulation about the purifiers is as follows: A quantity of lime is slaked (in an adjoining shed) by the addition of about an equal weight of water; a little over one-third its weight of water is taken up chemically, and forms the dry hydrate of lime (which is in fact the binding material of ordinary lime-mortar), a portion of the water is evaporated, and the remainder or excess of water gives the requisite dampness for the process of purification. Unless compacted by stirring or beating, the slaked lime has about twice the volume of the quick-lime and about twice the weight, and in this condition (for it is desirable that the mass should be as porous as possible) it is removed to the purifying house to be spread upon the trays as described.

"After a purifier is charged and put in its place at work, the foreman of the purifying-house will test the gas in it from time to time. The test is performed by the exposure of two strips of paper to a small stream of gas, which is allowed to escape by a cock on the covers of the last purifier put in use.

"These papers have been prepared, one for a sulphur test of blotting-paper wet with acetate (sugar) of lead, which blackens quickly if any sulphur be present; and the other, impregnated with litmus or turmeric solution; litmus becoming blue, and turmeric red, if any ammonia exists in the gas.

"So soon as the sulphur-test shows the presence of sulphur in the last box, it is time to change and bring into action, as first and second purifiers, those which will take their place in due sequence, and which have not been so much '*fouled*' as to cease to act properly; and it results from this changing, by *test*, that there will *not* be a change of purifier each day, but only, whenever necessary; the construction of the apparatus, however, having been planned for proper distribution of labor, to give a daily change to a set, when in regular work.

"The test having given the legitimate indication, the last purifier of a set is thrown out to be cleaned; and the centre-valve being shifted, a large nozzle (which is to be found on each cover) is opened to release the gas enclosed in the box, when the cover is lifted by a traveling apparatus for the purpose ('*carriage*') and transported away (over the boxes in use); and after an interval of time for the dissipation of the enclosed gas, the workmen commence the removal of the '*foul-lime.*'

"This foul-lime is taken in wheel-barrows and removed into the open air. The place of dumping is forty feet from the purifying-house, in an open yard on the bank of the Schuylkill, about forty feet from the edge of the wharf along the river, and about one hundred and fifty feet distant from Chestnut street Bridge. The level of the wharf is about thirty feet below the roadway of the bridge, and the level of the purifier-house floor about six feet above that of the wharf. A low wall, forming an angle, supports the bank at the dumping place, and the foul-lime is deposited in a heap from the top of this wall.

"At the time of my first visit to the gas-works, in February, 1876, there was a barge receiving the spent-lime from carts, which were hauling it across the short space of the width of the wharf; on the occasion of a subsequent visit in March, 1876, there was none going away, but a number of laborers were breaking up frozen foul-lime from the bottom of the dump where it had collected. I was told that, generally, there were barges ready to receive the material, but not always, and that sometimes the foul-lime was hauled away in carts and wagons;—whenever a farmer came for it, it was given to him.

"To a visitor of a gas-works, where the delicate sense of smell is quickly impaired, the foul-lime in the purifiers is not exceedingly offensive, and at the moment of discharging one of the boxes and of the dumping of the material in the heap, the offensiveness is not so decidedly evident; but after short exposure to the air, and especially to damp air, or when, having become wet, it is permitted to dry in the sun, the propagation and dispersion of effluvia is disgusting, even to those employed in the works, and whose business it is to endure the smell. A somewhat active decomposition of some of the constituents of the foul-lime certainly occurs after exposure to the air, as is evidenced by an increase of heat, and it is certain that this decomposition does not destroy the odoriferous substances.

"In the analysis and purification of gas, by the Rev. W. R. Bowditch (one of the most practical scientific writers on the subject), 1867, will be found (folio 19, *et. seq.*) these words:—

"'About this date (1844) the use of gas was increasing very rapidly, and gas companies in London and some large towns were sadly encumbered with, and troubled about, the lime refuse which arose from purifying their gas. Purified the gas must be. Sanitary regulations most properly prohibited the running of Blue Billy (the

foul liquor of the original wet-lime purification process) into streams and rivers, and even, in some cases, prohibited the carting away from gas-works of dry-lime refuse during the day-time. Matters seemed to be approaching a crisis, when, in 1849, Mr. Hills came to the rescue, and introduced sesquioxide of iron as a purifying agent instead of lime.'

(To be continued.)

TIMBER NOMENCLATURE.

[From the *Timber Trades' Journal.*]

It is impossible to take up any feature or subject so closely associated with the common wants of man as that of timber, without finding in its name something of absorbing interest. As a material it ranks second to no other, either in connection with man in his rude and primitive state or under the high polish of civilization; so closely is it associated with his everyday life that we may say of it as of his shadow—it is always with him. A mere glance at the vocabulary pertaining to timber shows that it abounds in monosyllables, and that words of a compound character are the exceptions. This fact points with unerring truth to the rude and simple language of our Saxon ancestors as the source from which it is drawn. We find, so far as this country is concerned, that the Celtic and the Roman "tongues in trees" have failed to reach our times, and that names of a Norman origin occupy no prouder position than parasites upon the grand old Teutonic stock. The study of this subject carries us back to an early period in the Christian era, when our eastern coast was called the "Saxon shore," when every creek and river mouth of this fertile spot "set in the silver sea" was infested with the blue-eyed strangers of the north; it shadows forth a time when like a wave this intruding race swept over the land, blotting out in its devastating course the vernacular of its predecessors, and setting up a standard tongue which, with sundry changes consequent upon the wearing effects of time, has endured to the present day.

Ash, in alphabetical order, claims our first attention. It is the "aesc" of the Anglo-Saxons, and the "ast" and "ask" of the Swede and Danish dialects. From being the wood of which the lances, spears, and shields of our forefathers were made, it became

par excellence the tree of war, and, unlike its present feminine, the "queen of the woods," was endowed with masculine attributes. It held the high distinction of being the personification of strength and valor, and it was a tenet of the heathen faith of the northern nations that the first man Æsc was made from the wood of this tree. From this belief it became a personal name of the highest honor, to be worn only by those of royal blood. Æsc, the son of Hengist, is an instance of its application in historic times, in which case it implied that his genealogy was traceable to this ancient source. It is noteworthy that the Greeks and Romans made their spears or pikes of this wood, a custom also obtaining with the Saxons, who called this warlike instrument an "aesc."

Balk, or "baulk" as applied to a log of wood, is from the Saxon *balc*, the German *balken*, and the Dutch *balk*. In the former dialect, it had a more extended meaning than it bears at present, as we find it implied a beam, a roof, a covering, or a balcony.

Batten is from the Saxon "bat," a boat or ship, and implies a piece of wood suitable for making or building such vessels. The club or bat of the cricketers, as applied to a piece of wood, is allied to this word.

Beam, from the German "baum," a tree—in the sense of a tree, the word still lingers with us in horn-beam—horn-tree, its primitive meaning was a rough-hewn tree used for constructive purposes.

Board is the Anglo-Saxon "bord," and German "brade," a thin plank. This word has been highly wrought upon, from being made of boards, we find it applied to the deck of a ship, also to a table, and hence those that assemble round it, and even the food placed upon it.

Charcoal is a compound of the Russian and Anglo-Saxon tongues; "char" is to burn or reduce to coal or carbon, and "coal" is a term referable to a black substance. Charcoal means literally wood reduced to impure carbon by expelling the volatile matter. In the early history of the iron trade of this country, it was an ingredient of the first importance; our present name for fossil coal is borrowed from this material. When made from beech-wood, it was called "beech-coal." Charcoal burners were called colliers, an occupation or calling which furnished the family names of Collier, Collyer, and Colyear.

Chestnut, sometimes called Spanish—from the fact of the best fruit coming from that country—is from the Anglo-Saxon "cyst-beam," literally the fruitful tree; being a tree requiring a warmer climate to ripen its fruit than that prevailing in this country, it is naturally inferred that it was a tree little known to our rude ancestors. Be this as it may, the fact remains that they were present at its christening. The horse-chestnut was so called upon its introduction from Asia in 1629, the term being a mere translation of its classic name, *hippocastanum.*

Deal is the Anglo-Saxon "dael," and the German "diele," a part or portion, hence a piece of wood. In early times it most probably referred to a riven piece, as a riving axe was called a "deal axe;" we still retain the word in "a deal of cards," meaning a division or portion of the whole. So far as the timber trade is concerned, the term "deal" appears to have been applied alike to the fir and the spruce, the "mast-tree" and "deal-tree" being common terms long before it was known what trees they were the products of.

Elm, from the Anglo-Saxon "elm," "ellm," or "ulme," and the Dutch "olm." This name occurs, with slight variations, in all the Celtic dialects. From the fact that the elm rarely ripens its fruit in this country, coupled with the resemblance of its name to the classic *ulmus,* it is looked upon as a doubtful native. The term "wych elm" is supposed to refer to its ancient use for water pipes, especially in connection with salt-springs, erroneously supposed to have been called "wycs" and "wics," as in Nantwich, etc. The writer is of opinion that the term "wych," also referable to the hazel, and the mountain ash, is merely a varied form of "withe," a lithe or pliant rod or twig.

Fir, as a term, embraces all the best known coniferous trees, such as the Scotch fir, the spruce fir, and the silver fir; it applies to trees of a resinous character, easily ignitible, and consequently suitable for fuel, for torches, and firebrands. Gerard says, "the fir-tree" was originally the "fire-tree," an inference that all investigations confirm, and there can be no doubt upon comparing the Anglo-Saxon "fyr," fire, with the Scandinavian "fyrre," fir, that the terms "fire-wood" and "fir-wood" are synonymous.

Forest is an Italian or Armenian word which has reached us through our French or Norman connections; it appears in the German language as "forst." Our ancient forests were called "woods,"

as in Sherwood; but the intruding term, although superfluous, has tacked itself on behind, hence the common phrase "Sherwood forest." The Saxon "woodward," from this change of dialect, became the Norman "forester;" as an occupation it was of sufficient importance to found a large family of personal names, hence those of Forrester, Forster, and Foster.

Log is an old Dutch term for "heavy," hence a heavy piece of timber is so called. The equivalent in the German tongue is "klog." In America, where the mother tongue is subject to great mutations, the act of rafting timber has got corrupted to "logging."

Lumber, dry, household rubbish, has taken the place of the term "wood" on the American continent. With the early settlers, whose all lay in the cultivation of cereals, timber was an incumbrance to the land; and although it has long since raised itself into a marketable commodity, it has failed to free itself from this term of ridicule.

Oak, the Anglo Saxon "a′c," "aec," and "aac," and German "Eich." The first form is preserved to us in the fruit "a′ccorn," the corn of the oak. In ancient times it was a tree prized for its fruit, being used for fattening swine, and, in time of dearth, as human food. Oak woods were estimated by a number of hogs they would fatten, proof of which we find in the Doomsday Survey, where woods of a single hog are enumerated. Pliny says, in his time acorns formed the chief wealth of many nations. The etymology of this word is difficult to arrive at; it appears to be a term peculiar to the north of Europe. We find it in "ac-drenc," oak-drink, a drink made from acorns, and "ac-wern," a squirrel. This interesting animal was known by this ancient name before we borrowed the present one from our French neighbors.

Plank runs through the French, Dutch, German, and Danish languages with little variation. It implies a flich of wood, thicker than a board. It is a term which no doubt reached us through our early trading connections with the Low Countries.

Poplar, like all other trees, whose names rise above simple monosyllables, is supposed to be introduced. The white and the aspen poplars are the trees with which our forefathers were familiar; the black and the Lombardy varieties being recent introductions. It is generally thought that this tree was introduced as early as Roman times, an opinion which derives support from the resemblance of the name to the Latin *papulus*. It is supposed by some writers to have obtained this classic name from its being the tree selected for the

decorations of Rome, *arbor populi*, by others from its leaves being as easily agitated as the minds of the people. It is curious that Sir Walter Scott uses this simile:—

> "Oh, woman, in our hours of ease,
> Uncertain, coy, and hard to please;
> And variable as the shade,
> By the light quivering aspen made."

Spruce occurs as Spruce fir and Norway spruce. The former is the older or original term, and if rightly read is simply descriptive. Spruce fir is the old Prusse, or Prussian-fir. It occurs in the manuscript of *Liber Albus* (*circa* 1250), as "pruz-fir." It would appear that there was little or no distinction in these early times between Prussia and Russia, as the Russian leather of our day was the Spruce leather of the Dutch merchants, who, during the Hanseatic League, had their seat of trade at Wisby, in the Baltic. It was through their instrumentality that the produce of the Baltic shores reached England *via* Amsterdam, and from this cause may be traced the numerous lowland terms that abound in our nomenclature of timber. It will be seen that as the timber trade moved to Norway, the term spruce accompanied it, and hence "Norway spruce fir" has long been held as the equivalent of "white deal." The same remark applies to America, where "spruce" stands for the "white fir" of that continent. In unearthing the meaning of these ancient terms, the first form in which they were used contrasts strangely with their present use. In the case in point, we should scarcely be credited with the exercise of sound reason were we to write "American Prussian fir" for "American spruce fir," although such term would be orthographically correct.

Stave, from the Anglo-Saxon "stæf," a staff, stick, or pole. It occurs in "flag-staff," "ladder-stave," and cask or pipe-stave," and implies a light round pole, or a hewn or riven piece of wood, smaller in character than a deal. In mediæval times the term stave was largely used in connection with bows. It is certain that bow staves were of ash, elm, and yew, but the term stave is now wholly associated with the oak, and there can be little doubt that staves for the cask trade have been made of this wood from the earliest times. It is a point worthy of investigation whether the wainscots of the fourteenth century were not riven staves for the cooper; certain it is that their value was only one-fifth that of bow-staves.

(To be continued.)

Chemistry, Physics, Technology, etc.

PETROZCENE AND ITS PRODUCTS.

By Dr. Herbert W. C. Tweddle.

Petrozcene is a hydro-carbon and a product of the dry distillation of the residuum, or tar, from petroleum. It sublimes over at the latter end of the distillation, accompanying a thick resinous oil of about ·980 specific gravity.

In its crude state this mixture of oil and petrozcene is bright orange in color, which rapidly becomes dark green on the surface by oxidation; hitherto this substance has been almost valueless. From it petrozcene is separated by lixivation with benzine and when thoroughly separated from the oil, it is obtained as a yellowish green crystalline, extremely light precipitate.

If only the early product of the last portion of the distillation is lixiviated, the precipitate obtained is a canary yellow and is called "Thallene," this substance was examined by Prof. Henry Morton, to whom I sent some for examination, (*vide* Journal of Franklin Institute, Vol. LXIII, Third Series, page 296, and Vol. LXIV, Third Series, page 273, A. D. 1872).

Petrozcene fuses at 420° to 425° Fahr. Its specific gravity is 1·2066. It is crystalline and dark olive green in color, not very hard, but brittle. After fusion, if heated to 500°, it sublimes, giving copious yellow vapors, which, if it is desired to collect, require a large condensing surface. If heated in a close vessel to about 600° it distills over rapidly, (the still must have a large fire surface, a very short condenser kept at least 300° to 400°, and made to drop with steep incline) and deposits in the still a large amount of separated carbon. It is inflammable and burns an extremely sooty red flame, emitting a slight pungent empyreumatic odor.

After fusion, if poured out, it chills rapidly, but retains heat VERY tenaciously. In cooling it shrinks very much, cracks and sometimes falls to pieces, its surface is crumpled, somewhat iridescent and metallic in appearance, its fracture in large masses exhibits a highly crystalline structure.

The crystals are thin uranium green colored plates, transparent, and of a foliated structure, resembling some varieties of graphite. When petrozcene is kept fused at a high temperature for some hours it is partially decomposed, and when cooled in masses of one or two hundred pounds, separated carbon is found permeating the entire interior structure, in this state the crystals are very beautiful, resembling spiegeleisen, though not so large.

When petrozcene is distilled in large quantities, and proper care exercised, it can be separated into a series of interesting and beautiful products, in fact I know nothing distillable (if I may use the word), among organic or inorganic bodies, that affords such beautiful kaleidoscopic effects from the beginning to the end of the operation. The products I classify as follows:—

The first product is water, accompanied and followed by a yellow-green sublimate which I collect and call "petrozolene," it fuses at 373° to a light green crystalline body. This gives off a white vapor with an empyreumatic odor, a little above its melting point; accompanying this sublimate is a distillate which chills rapidly with a brilliant green surface; it is semi-transparent and much more crystalline than petrozcene, in large masses it is very beautiful, this substance I call "carbozcene," it fuses at 398°, and commences to volatilize at 470° Fahr., giving copious yellow vapors.

This distillate is succeeded by another, requiring a higher temperature to distill, it is brownish green in color, crystalline, and fuses at 422°, volatilizing at 550° Fahr., this substance I call "Bi-carbozcene."

At this point the green sublimate, petrozolene, disappears and is succeeded by a golden orange sublimate which continues to the end of the distillation, this I call "Bi-petrozolene," it fuses at 442° Fahr. to a dark brown crystalline body.

The third portion of the distillate is bronze yellow in color, crystalline, fusing at 452° Fahr. and volatilizing at 480° Fahr., this I call "Tri-carbozcene."

The fourth portion of the distillate is dark orange in color, accompanied by copious vapors of Bi-petrozolene; it is crystalline and fuses at 460°, its volatilizing point is above 550°, this body I call "Per-carbozcene."

The fifth and last portion of the distillate changes rapidly in color to a dark bronze green, almost black; it is crystalline, and shrinks and cracks to pieces on cooling, this I call "Carbo-carbozcene," its fusing point I did not get.

The residue in the still is a heavy intumesced mass of carbon, (which I will analyze, and send result at some future time).

All the sublimates when in powder lose in a few days their brilliant colors by exposure to light, assuming superficially a buff tone.

Petrozcene is readily oxidized by boiling with Bi-chromate of potassa and nitric acid, producing a red compound, nitro-petrozcene, which is susceptible by chemical treatment of producing fast dyes and colors. Petrozcene is carbonized by sulphuric acid, it is insoluble in water and glycerine, partially soluble in alcohol, benzine and turpentine. It resists the action of caustic potash, soda or organic acids. It is odorless, and rubbed between the fingers, it is at first yellow, then green, and has a resinous feeling. It is not a conductor of electricity.

It and its products are highly fluorescent (the green fluorescence of petroleum, paraffine oils of commerce is due to it). Whether petrozene will become commercially valuable the future will determine; but to the scientific world it will no doubt be a study of great interest, not only for its novelty but for its close analogy to some of the metal group, and its peculiar fluorescent properties (see Prof. Morton studies, before referred to, on "Thallene").

Between petrozcene and its products and sulphur there is a marked analogy, as far as physical characteristics are concerned, but no further. In manufacturing it, it irritates the skin somewhat, and it has this peculiar effect, that if you work with it too much, either by itself or among its subliming vapors, you get some green in your eye, *id est*, your vision sees objects green instead of their proper color. This, however, passes away after some hours. It is not poisonous when taken internally in small quantities.

Petrozcene can only be produced in limited quantities: 50,000 barrels = 2,100,000 gallons of Pa. petroleum, of 48° Beaumé, spec. grav. yielded only four hundred pounds of petrozcene precipitate, although this might probably be increased by proper treatment in the earlier stages of manufacture.

The resinous oil which accompanies the petrozcene is recovered from the benzine washings by distillation, and produces a valuable paint oil and varnish, which oxidizes rapidly and dries hard.

Very small portions of the sublimates can be procured, but of the crude petrozcene and its distillates, I have obtained so much as to be able to give, in moderate quantities, to scientific men for experimental purposes.

TABLE OF PETROZCENE AND ITS PRODUCTS.

Petrozcene fuses at . . .	426° Fahr.		Color is dark greenish-yellow, becomes dark olive green and crystalline by fusion.
" specific gravity	1·2066		
Thallene fuses at	406°	"	Color light canary yellow, fuses to a dark green crystalline body; volatilizes a little above its fusing point.
Petrozolene fuses at . . .	373°	"	Is a green sublimate from petrozcene; it fuses to a light green crystalline body.
Bi-Petrozolene fuses at . .	422°	"	Is a golden orange sublimate from petrozcene; fuses to a dark green crystalline body.
Carbozcene fuses at . . .	298°	"	Is a light green crystalline distillate from petrozcene.
" volatilizes at .	470°	"	
Bi-Carbozcene fuses at . .	422°	"	Is a brown green crystalline distillate from petrozcene.
" volatilizes at	550°	"	
Tri-Carbozcene fuses at . .	452°	"	Is a bronze yellow distillate from petrozcene.
" volatilizes at	490°	"	
Per-Carbozcene fuses at . .	460°	"	Is an orange colored crystalline distillate of petrozcene.
" volatilizing point too high to obtain with mercury thermo.			
Carbo-Petrozcene, fusing point unknown.			Is a dark bronze green crystalline distillate of petrozcene.
Nitro-Petrozcene, bright red compound.			
Petroleum Mastic, specific gravity 3° Bauum Hydrometer.			This oxidizes rapidly like boiled linseed oil, and will make good varnish, and is the only product of Pennsylvania petroleum that I know of that will oxidize in this manner.

It is somewhat to be regretted that the names for these apparently new hydro-carbons, have been assumed by the writer of this article before analysis had designated their place in the scale, and established the appropriateness of denomination. It is however proper that a priority of discovery should be asserted at this time by Doct. Tweddle. —Ed. F. I. J.

USE OF SODIUM SULPHIDE IN TANNING.*

By W. Eitner.

[From the *Journal of the Chemical Society*, June, 1876.]

Tanners have long since perceived that lime does not in all respects afford the means of preparing the skins for a thorough tanning. After some speculations, they have succeeded in improving the lixiviating process.

The favorable action of soda when added to the lime having been noticed, three depilatories were used, viz., the long-known "rusina" Böttger's green lime and gas green lime, each having hydrosulphide of calcium as acting substance. These agents were applied to the hair side of skins, and in a few hours dissolved the hairs in proportion to the quantity of sulphide they contained. The hair was of course rendered perfectly useless, but by macerating the flesh side with lime, it was not destroyed; moreover, the skins did not lose any valuable substances.

Lindner (1855; 137·221) prepared an aqueous extract of the above agents, by which a large portion of impurities was removed, and dipped the skins in this clear solution, the strength of which can be regulated by a Baumé's hydrometer. The skins were thus cleansed much better and more quickly, and experienced tanners, like Kampfmeier of Berlin, considered the leathers produced by this method superior to limed leathers.

Sulphide of lime, however, in its above-mentioned forms has several disadvantages. In the form of rusina it was commercially too expensive, and containing poison could not be recommended. Böttger's green lime also is too dear, and the smell of sulphuretted hydrogen it causes in works is disagreeable; gas-lime, however, is at present very

* *Dingl. Polyt. J.*, ccxviii, 355—361, 437—453, and 508—517.

scarce. It was therefore necessary to obtain alkaline sulphides cheaper than sulphide of lime.

M. Louis Matern, of Antwerp, exhibited at Vienna in 1872 a new depilatory liquor, and an apparatus constructed by him, by which skins treated with his liquor were depilated.

The author analyzed this liquor, and found it to contain slaked lime, soda and sulphur approximately mixed, but as the specially acting substance he discovered sodium sulphide. M. Matern evidently thought that the total mixture and not one special substance produced the desired effect, and used it merely for depilating sheep and goat skins.

Eitner in 1873 treated skins of calves, bullocks, and horses with this liquor very successfully, finding from the commencement of his experiments that the mixture was the more effective the more sodium sulphide it contained, and he therefore resolved upon using this substance exclusively. He obtained perfectly pure sodium sulphide from de Haën, and the results of the depilation were very remarkable. Bullocks' skins were depilated in 15 hours, and calf skins in 4 hours. De Haën at once understood the importance to be attached to this re-agent, and therefore began to prepare it on a large scale.

The author next describes the uses of sodium sulphide as special depilatory in the manufacture of under-leather, in the first place strictly in regard to sole-leather, and secondly with regard to thin leather, as used for the inner soles of boots.

In the case of the sole-leather, loosening of hair is the only object in view, and this is effected either by the different sweating processes, or by placing the skins in fermenting barley-groats, &c. The skin is said to be only slightly altered in its outer parts, the real leather and other parts retaining their natural condition. This latter fact, however, is ensured much better and more safely by using sodium sulphide, and in this case this method will be seen to be in conformity with that of sweated skins, whereas with other kinds of leather, the tannin has to be modified. The following constitutes the depilatory operation:

The skins are spread out flat upon each other on their flesh side, and then painted with sodium sulphide, care being taken to brush the solution over the hair in such a manner that it touches the skin. After this is done the skins are folded together, put in a warm place

not below 19°, and covered with a wet rug, to prevent them from drying. In about 15 hours the skins are ready for depilation.

The solution is prepared by dissolving a weighed quantity of crystallized sulphide of sodium in hot water, using 1 kilo. of the salt and 2 litres of water. This solution must be thickened with lime, using 3 parts to 1 of sodium sulphide. The quantity of sodium sulphide required in depilating the skin of a bullock varies, according to the size of skin and quantity of hair, between 100 and 120 grams. Dried skins require 17—35 grams more salt.

It is necessary to apply the solution to all parts of the skin, more especially to the head and along the back, and to remove any stones or coarse sand from the lime, which prevents the solution from acting. It is also a matter of course that the skins should be soft before treatment, and if dirty on the hair-side, they should be well cleaned.

Before removing the hair it is advisable to wash the skins in water in order to get rid of the caustic depilatory, otherwise the hands of workmen would suffer very severely. The washings need not be saved.

After removing the hair, the skins are placed in fresh and hard water, partly to wash them, but partly also to swell them, because without this the fleshing of the skins would be rendered very difficult and perhaps impossible. The leather clippings obtained from the fleshing are identical to those of sweated skins, and must be treated with lime before boiling them up for glue. After the fleshing, the skins are treated in the usual manner, and tanned like sweated skins.

With regard to the manufacture of the second class of under leather, viz., leather used for inner soles of boots, the results were not so favorable with sodium sulphide.

The main part of the tanning of such leathers is not entirely effected in the pit, where the acids are formed, and which, next to tannin, are the most important agents in the preparation of under leather; but a preparatory tanning already takes place in the ooze, which latter represents the principal feature in the manufacture of upper-leather. The difference between this under-leather and sole-leather is sufficiently marked by the edge and the felting of the fibre.

In tanning sole-leathers, the outside of the skin is only colored in the ooze, and the at first dead and shriveled fibre is swelled by the

acids, and in this state, by the action of acid and tannin on the natural fibre, it is converted in the pit into leather.

Inner sole-leathers which were formerly treated with lime, and although they lost part of their grain, were nevertheless brought into the ooze in the swelled state, do not at first require acids for the swelling, but so much the more tannin to prevent them from being spoiled. This tannin enters into the leather with comparative quickness, because it is absorbed much better in the ooze than in the pit, and because the lime, which dissolves and removes many portions of the skin, thus leads the way into the inside of the skin. These leathers therefore contain more tannin and less acid than sole-leathers.

Skins depilated with sodium sulphide, as already mentioned, completely resemble those of sweated skins, but differ from limed skins; the former therefore in their first period of tanning require another treatment.

Under all circumstances skins depilated with sodium sulphide are less swelled than limed skins, and become less swelled in solutions in which limed skins become well swelled, because the former have obtained a preliminary swelling through the lime, whereas the latter are still in their natural condition. The oozes in which these skins are to be tanned must therefore contain more acid than lime-oozes. From the degree of tanning and swelling of the skin tanners are able to determine whether skins are ready for their second treatment. The reason why the tanning is slower and a larger quantity of tan has to be used is the following: In the first place these skins contain more material to be tanned, for nothing has been taken out; and secondly, their texture is for this very reason firm and close, whereas lime loosens and partly destroys it.

The addition in the quantity of tannin can take place at either of the following two stages. We can either give the ooze more material in the first tanning, by adding more tan or using one or two more tans, and thus obtain a leather of greater firmness and suitable weight; or we can use the ordinary number of tans, but allow every separate set to stand for some time after having added more tan. In this case we form a leather which is more like ordinary sole-leather.

Tanners who work with galls, valonia, and myrobalans can use the first method, but to those working with tan the latter method may be recommended.

The last-described process can be used only when the hair side of skins has been treated with sodium sulphide. Hair, however, is often too valuable to be totally destroyed, which of course would be the case in the above, but if the flesh side of skins is treated the hairs will be only partly removed.

A well-known tanner gives the following account with regard to this defect and the means of remedying it:—

After treating the skins, they were placed in layers and left to themselves for some time till the hairs became loose. They were then hung up and allowed to run off every two hours, and after 6—10 hours could be easily and completely depilated in the fulling trough. It was further noticed that leathers treated on the flesh side dried very quickly, and that this circumstance prevented the depilation. In order to remedy this defect, the writer placed the treated and folded skins in a tub full of water. The skins were well swelled and gradually rose above the water, because they increased in volume, and the hair could be removed from all parts of the skin. Skins treated with sodium sulphide are said to have 10·4 per cent. more weight than limed skins.

The tanning in this case must be effected in the following manner: The fibres of such skins have already begun to swell, and therefore do not require those powerful agents, *i. e.*, larger quantities of acids, which sweated skins require. The ordinary tans are sufficient.

The author thinks that the lime will soon be superseded by sodium sulphide, because it is very essential in the summer to hasten the first operations, and also because a better quality of leather is obtained, which latter will henceforth be the watchword of the tanner, for the American hemlock-leather competes very successfully with second-class leathers tanned in Germany, and therefore the author believes that, in order to insure the manufacture of first-class leather, the skins must in the first place be treated with sodium sulphide.

Eitner admits that there are tanners who still object to the use of sodium sulphide in the manufacture of upper-leather, but he thinks that they have not applied it properly, and insisting on their old method, have not considered the slight modifications which have to be made.

Tanners have hitherto been of opinion that skins treated with lime give upper-leathers combining firmness with softness. Eitner does

not dispute this fact, but states that lime removes valuable substances from the skins which sodium sulphide will not do, and he therefore recommends the following method:

The skins are soaked, stretched, and if possible fulled. A very careful stretching is enjoined by the author. The skins are then treated with the above-mentioned mixture of 1 part of sodium sulphide and 3 parts of slaked lime. The quantity of sulphide required for each skin depends on the quality and size of the skin, on the quality of the sodium sulphide, on the larger or smaller degree of softness, also on the quality of the lime mixed with the sulphide, and finally on the hardness of the water used, as a portion of the sodium sulphide is fixed by the constituents of hard water and is thus rendered ineffective.

Certain varieties of lime may contain substances which combine with the sodium sulphide, and in such quantities as to completely neutralize the action of the latter. Taking also into account the various qualities of sodium sulphide, which are often much lowered when the salt is kept for some time in a damp place, or badly packed, it is easy to see that absolutely exact numbers cannot be given in all cases, and that only the skill and experience of the practitioner can determine the proper quantities to be used.

Under normal conditions, *i. e.*, a medium article in strength, size, and softness, medium hard water (10°—20° of hardness), pure lime, good and new sodium sulphide, we require for a piece of

Green bullock's skin	105—175 grams.
Dry " "	123—193 "
Dry kips	88—123 "
Dry calf-skin	35— 53 "

The macerated skins are folded together, their flesh side being inside and their hair side out, and are then placed in a tub and covered over with water. After 12—24 hours the skins are ready for depilation. For the further working of the skins two methods may be employed. In the first the skins after depilation are scraped, which can easily be done, as the flesh side was exposed to the action of the sodium sulphide. The heads are then cut out and the skins eventually shaved. The author here mentions the treatment of leather straps used for machines—a mean between sole and upper-leather. The skins when depilated and shaved are placed in soft water and soaked for 2—3 days, when they are again trimmed. After

being stretched they are soaked in water for a short time and are then ready for tanning.

The solutions must be only very slightly acid; and they may be used more concentrated than usually; the number of tans used must never be below eight. By adding 250—500 grams of bicarbonate of soda the solutions will be kept neutral, or we may add ½—1 kilo. of salt, which, in spite of the acid, will prevent the leather from becoming too hard.

Eitner now returns to the upper-leathers which had been scraped and shaved. The upper-leathers which had been scraped and salted are not swelled to the same extent as in the lime process, still they are in a state suitable for tanning. Before doing this it is advisable to clean them. About 5 kilos. of oat-straw are boiled in 110 litres of water, the liquid cooled, the straw picked out, and the skins placed in this solution. If the dung of birds or dogs has to be used, the solution must be made with cold water and the skins treated in the cold. The skin can now be tanned.

In using the ordinary tans the skins swell too much and become too hard, but with extracts they tan exceedingly well. We must therefore work differently if we employ the usual method of tanning, adding bark. The skins are treated exactly in the above-mentioned manner till the depilating process has been finished, but after this they are once more placed in the same vessel in which they were washed after treatment with sodium sulphide. By placing them in this vessel the greater part of the active sodium sulphide is regained and may then be used for swelling the skins. For new and thin calf skins the solution alone suffices, but for harder qualities of leather more sodium sulphide must be added, using about 35—88 grams for a bullock-skin, 27—53 grams for a kip, and 13—22 grams for a calf-skin. The further operations are, with the exception of the smoothening process, quite in conformity with those used in the lime-swelling process.

The use of sodium sulphide is very essential in the manufacture of deer and kip-leathers. As is well known, it is very difficult to work these skins into leather, as most kinds possess a strong and coarse fibrous texture, and good leathers can be obtained only by the use of good and special means. The skins must in the first place be well soaked and be brought into the ooze as quickly as possible. Where there is no good river water for soaking the skins, soda must be added

to the well water. Sodium sulphide, however, answers better, adding about 17—53 grams to the water. The skins can thus be soaked much more quickly and are then ready for their further operations.

For treating most foreign skins lime alone was found to be insufficient and arsenic had to be used. On adding realgar or orpiment to the lime the sulphur in the ooze combines with the lime to form sulphide of calcium, a substance similar to sulphide of sodium. As the sulphur and not the arsenic acts in this case, and as the latter is very expensive and dangerous, sodium sulphide could be more favorably used. For very hard skins twice the normal quantity of sodium sulphide may be used without fear.

In the manufacture of horse-leather a portion of the skin, viz., the back part, is always tougher than the other parts of the skin, and therefore requires more sodium sulphide. The tanning of these leathers is performed in well-prepared solution, which can afterwards be more concentrated with tannin, as it is very advantageous to strengthen the ooze by adding extracts to it. The use of extracts deserves the highest attention as regards the quality of the leather and the profitable consumption of the tannin materials.

The tanning of pig-skins also belongs to that of upper-leathers. These skins are generally very loose and the large amount of fat they contain renders the process more difficult, as the lime-soap formed can only be partially removed and thus hinders the tanning. By using sodium sulphide this soap is converted into a substance soluble in water.

Manufacturers of morocco-leather have adopted the use of sodium sulphide, because the lime frequently spoils these kinds of leather. The author would like to know whether the wool obtained from these skins treated with sodium sulphide shows the same defects as that of skins treated with lime. He thinks that the former will wash better, as the fat has been removed and does not require a separate treatment with soda, as is the case in the lime process.

With regard to the manufacture of kid-leather, Eitner states that its treatment with sodium sulphide is fully described in No. 13 of "Der Gerber," and that thus the question respecting the use of sodium sulphide is settled for the present in all the branches of the leather industry.

The author in conclusion states that the results of his method depend on the quality of the sodium sulphide used. He recom-

mends it to be used in a tolerably pure state, and asserts that the less damp and the more bright and transparent it is, the better will be the quality. The amount of acting substance varies very considerably, a difference of 30 p. c. having been found in various trials. These differences are due partly to the decomposition and changes of the salt, but partly also to its manufacture, some samples having been found to consist chiefly of caustic soda, which absorbs moisture and carbonic acid from the air, and is converted into common soda, and thus loses its action. This latter circumstance explains why many tanners in Germany add lime to the sodium sulphide. The latter having been kept for some time was chiefly converted into carbonate of soda, which alone has only a very slight action, but by adding lime, caustic soda was formed, which acts more strongly and partly replaces the sodium sulphide, though in a very imperfect way. It is also very essential to keep the sodium sulphide in a dry place in well-closed vessels, and the tanner is advised to use it as quickly as possible, because the longer it is kept the less valuable it becomes.

For experiments on a small scale Eitner recommends not to buy the sulphide, but to prepare it according to the following method :— 3 kilos. of lime are placed in an iron vessel and slacked, after this 55 litres of water and 6 litres of cryst. soda are added and the mixture heated and agitated. As soon as the boiling commences, 1 kilo. of flowers of sulphur is gradually added and the whole boiled until the liquid assumes a deep golden-yellow color and shows no lumps of sulphur. The mixture is then allowed to cool, and may eventually be thickened with lime and directly used for working.

D. B.

Cornish Pumping Engines.—The number of pumping engines reported for June is 18. They have consumed 1751 tons of coal, and lifted 13,400,000 tons of water 10 fms. high. The average duty of the whole is, therefore, 51,600,000 lbs., lifted 1 foot high, by the consumption of 112 lbs. of coal. The following engines have exceeded the average duty :—

Crenver and Wheal Abraham	—Sturt's 90 in.	Millions	55·1
do. do.	—Pelly's 80 in.		52·5
do. do.	—Willyam's 70 in.		66·2
West Wheal Frances	—58 in.		52·1
West Tolgus	—Richard's 70 in.		61·8
West Wheal Seton	—Harvey's 85 in.		67·1
do. do.	—Rule's 70 in.		60·1

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

Vol. CII. OCTOBER, 1876. No. 4.

EDITORIAL.

Notice.—The publication of the Journal is made under the direction of the Editor and the Committee of Publication, who endeavor to exercise such supervision of its articles, as will prevent the inculcation of errors or the advocacy of special interests, and will produce an instructive and entertaining periodical; but it must be recognized that the Franklin Institute is not responsible, as a body, for the statements and opinions advanced in its pages.

The Explosion on H. B. M. S. S., Thunderer.—Forty-five lives have been lost by the explosion of a boiler, on the fourteenth of July last on board the British man of war *Thunderer*, the circumstances of which are well known to our readers from other journals, and will be found briefly noted by the Secretary of the Institute, at the meeting reported in this number of the Journal. The coroner's inquest which has resulted in a verdict of "accidental death," although accompanied with a finding that all the valves were stuck or closed down so that "the explosion resulted from excessive pressure," gives little satisfaction to any portion of the English community. Accidents *are* preventible and the end and purpose of a coroner's inquest, after an accident, is to exhibit judicially the circumstances of occurrence together with the malice or inadvertence which had allowed the disaster to ensue. It is the failure of the inquest to show either criminal or

inconsiderate cause for this accident that gives ground for so universal dissatisfaction.

The Coroner seems to have had the advice and assistance of one of the ablest of English engineers in this line of engineering, and as his opinion upon the facts coincided with the testimony of the few witnesses examined, and especially with the conclusions of the principal witness, F. J. Bramwell, C. E., and as all agreed in absence of malicious intent or blamable neglect, he did not recognize the desirability if not necessity of pursuing the inquiry to proximate causes.

It sounds somewhat like a paradox, to say that it is almost probable that any clear-headed lawyer, himself wholly uninformed on mechanical subjects, cross-examining the witnesses before a jury who were to be instructed from the very groundwork, would have elicited more information as to the cause of this disaster and the ways of prevention of future accidents, than has come out in this inquest.

Admit all the facts as given by Mr. Bramwell—and no other witness adds to them—a train of cross-examination which should have shown what constitutes a safety valve? what relation the steam gauge bore to the safety of the boiler? what caused the boiler to rupture in its peculiar way?—a kind of cross-examination which an uninformed person, who wanted to know, would have instituted, might have been productive of unexpected results. Thus with regard to the kind of valves called in this case safety valves—which proved so dreadfully misnamed, the general and accepted use could have been pleaded in showing no particular negligence or exceptional error in judgment—but were they safety valves? Upon such an inquiry it would have appeared if loosely fitted in the wings and easy in the guide at the head of the long spindle, they would have been likely to lift, so long as they stood upright, when the pressure in the boiler exceeded the resistance of the load of weights. Under this condition they would preserve a definite pressure in the boiler, but in sea service and with a rolling ship the effect of the weight would by no means preserve a definite pressure—a large portion of the load would be carried by the stems and wings. When the vessel rolled 30° the valves (if supposed to be divested of frictional resistance) would be relieved for 13·4 per cent. of the direct load, and at 45° of 29·3 per cent. That is, if the maximum normal load were equal to 30 lbs. pressure per square inch, the valve would lift at 26 pounds pressure in the first case, and 21·2 pounds in the second. This difference of pressure would be enough to

render a steamer unmanageable, as a man of war in a heavy sea, although it might be tolerable in the merchant service. [It was admitted that springs were substituted for weights in the latter service.] The load of weights on each valve was about 800 pounds and the weights were strung upon a spindle of $1\frac{5}{8}$ inches in diameter and about 18 inches long from the top of valve seat to the spindle guide. The swinging of this immense weight on a slender, soft (not hammer hardened) brass spindle, although in the quietest part of the ship, cannot be regarded as a desirable mechanical arrangement. But the use of three wing guides for the valves, in the seats, would meet the disapproval of most constructors. Four wing guides where there is any sidewise pressure are much less apt to bind—the angle of contact of the face of the guides with the side of the hole in the valve seat is much more favorable for four wings than for three. But the poppet valve with a pin guide is admitted to be preferable to any wing valve, for ease in lifting. To carry these heavy weights, and to close tight on the seats after the valves had once lifted, these valves had their wings and the top of the spindles well fitted. There were two valves in the same casting and the expansion of the pair of seats—directly exposed on their under side to the steam in the boiler, while the spindle guides at the top were comparatively cool, seems to have bound the wing guides in seats, so that the valves failed to operate at all, until some unknown, excessive pressure ruptured the boiler. The hand wheel lifting contrivance, by which one of the two safety valves could be forced up from its seat, in case it stuck, is a more than doubtful improvement as a substitute for the old lever and cord with which the fireman *felt* the pressure in his boiler.

The best American practice in safety valve construction is a loose disc valve, without any bottom guides whatever, the contact of the valve with the seat being ensured by guiding the spindle above and close down to the disc. The bearing surface of the disc is made a portion of a sphere, and the seat is a narrow edge of conformable shape; the disc is ground to fit the seat by a pestle and mortar movement, so as to be tight in whatever position contact is made, within some limit of looseness of joint between the stem and the disc. The lever bears upon the end of the valve spindle, and is threaded through a loose bridle at the top of spindle, the end of which lever is held by a balance spring, so that the fireman can test his safety valve at any moment. It is customary to carry a cord or chain from

the safety valve to the engine room, to allow the engineer to try the safety valve for himself if he chooses.

The areas of the safety valves for the boilers of the *Thunderer* were in accordance with good American practice, on the supposition of a combustion of not much over twenty pounds of coal per square foot of grate per hour.

Some persons are disposed to lay stress upon the negligence which allowed all the steam valves of the boiler which exploded to be or to remain closed; but, in an engineering point of view, this condition could not be considered as the cause of the disaster. The safety valves were intended to meet just this contingency; and if they had not been unreliable in the extreme they would, without the least question, have done so. Not that the negligence can be excusable, but that this particular negligence was one of the known chances of operating boilers, and the accident arose from the failure of the provision of safety valves to meet it.

The steam gauge was a snare and delusion. Are not all of them so? If there is an engineer who has not stood in stupid helplessness before a row of discordant steam gauges, and has not returned to *feeling* his safety valves to find where his steam was in his boilers, that engineer is in the British navy—he is surely not to be found elsewhere. Steam gauges, as well as glass water level gauges, when in order, have their place in the *convenience* in working of boilers, and, possibly, in the promotion of safety, in giving each of them one more sense (that of sight) to the fireman; but the safety valve which can be lifted, and the gauge cocks which can be blown, will for all time remain, preëminently, the tests of reliance.

The boilers were of an antiquated and nearly obsolete type—unsafe at any moderate pressure, and unsuited for use with an engine built in accordance with good practice within the past ten years. Their broad, flat surfaces invited accident, either from unavoidable imperfections, or the rusting away of the stays. These flat surfaces were stayed in 16 inch quiltings, by $1\frac{3}{4}$ inch screw stays (about 1·22 inches at the root of the threads), and the stays broke off or drew through the $\frac{1}{2}$ inch thick plate. The load on each of these stays was of course 256 times 30 pounds, = 7680 pounds, on 1·17 square inches of section of iron in the bolt, = 6600 pounds on each square inch. They would each, probably, have carried eight times this load, supposing none of them to have been strained in threading, and no

defect existed; but the limit of elasticity is reached at three times, and in screwed bolts from iron of 50,000 pounds tensile strength, this point (20,000 lbs.) is where the probability of failure from impairment or defect begins to have definite value; so that the stay bolts could not, in an engineering value, be taken as over *three* times in excess of their strength. But this admission of possible weakness in ever so small a proportion of the number of the stay bolts employed, should be applied to what happens when any one of them fails, and the effect upon the adjacent ones—whether in case of the failure of one stay bolt, those next to it could carry its load. When it is considered that the breakage of a defective bolt would be sudden, and the effect on those near it would be of the nature (in part) of a blow, and that the strain would not be a fair one, but, with a leverage, it is quite evident that this wide spacing trenched on the limits of safety.

The facts here given, and perhaps others, would have appeared in evidence if the inquest had been directed by any barrister without predisposition to show not only how, but why, this accident occurred. The dissatisfaction with the verdict in England is because this important point was not fully elucidated. If this was an *accident* pure and simple, and if the preceding catastrophes in the British navy were accidents, the belief that these iron-clads are very dangerous vessels will be quite generally entertained in Great Britain.

Franklin Institute.

HALL OF THE INSTITUTE, Sept. 20, 1876.

The stated meeting was called to order at 8 o'clock P. M., Vice-President Chas. S. Close in the chair.

There were present 60 members and 4 visitors.

The minutes of the last meeting were read, and after amending verbally, were adopted.

The Actuary presented the minutes of the Board of Managers, and reported that since the last meeting of the Institute, there have been 14 persons elected members of the Institute, and the following donations made to the Library:

Sixth Annual Report of the United States Geological Survey of the Territories, for 1872, by F. V. Hayden. Washington, 1873. From Hon. Chas. O'Neill, House Rep.

Minutes of Proceedings of Institution of Civil Engineers. Vols. 43, 44. Session 1875–6. Parts 1 & 2. London, 1876. From the Institution.

British Patent Reports, issued between Feb. 19 and May 13, 1876

Abridgments of Specifications. Wearing Apparel. Div. III. Foot coverings. Ditto. Harbours, Docks, etc., 1617–1866. Alphabetical Index of Patentees and Applicants for Patents, for 1873. From British Patent Office.

[List of Donations to the Library will be continued in next number.]

From the Committee on Library, the Secretary presented and read the following:

Phila., Sept. 15, 1876.

Mr. Jacob B. Knight, Secretary,

Dear Sir:—I send by bearer a collection of old volumes, chiefly on chemistry, numbering about eighty, which it is my purpose to present to the Franklin Institute; as also those I have heretofore deposited with the Institute, either bearing my name or that of my late father, Adam Seybert.

Very truly yours,

426 Walnut Street. Henry Seybert.

Mr. Bullock, Chairman of the Committee on Library, presented the following:

The donation of books made by Mr. Seybert numbers over 500 volumes, and is a valuable and acceptable gift. Some of the volumes belong to scientific serials, and serve to complete the sets to which they belong, now in the Library. The Committee on Library, desiring to properly acknowledge the substantial character of the donation, offers the following resolutions:

Resolved, That the thanks of the Franklin Institute be and are hereby presented to Mr. Henry Seybert, for his valuable gift of the books heretofore deposited with us; as also for the additional volumes lately received.

Resolved, That the Secretary of the Institute be directed to forward a copy of these resolutions to Mr. Seybert.

On motion the resolutions were unanimously adopted.

The Secretary reported from the Committee on Sciences and the Arts, that at its last meeting it recommended the award of the Scott Legacy Premium and Medal to Chambers, Bros. & Co., for their brick-making machine.

The Secretary presented his report, which embraced a new relay sounder for electro telegraphing, invented by Professors E. J.

Houston and E. Thompson, of this city; a steam canal-boat, the invention of Jos. W. Dilks, of Philadelphia; a grid-iron stage and depositing dock for docking vessels, the invention of Messrs. Clark and Stanfield, London, England; and an illustrated account of the causes leading to the explosion of one of the boilers on the British turret ship *Thunderer*;* and also a description, by Mr. R. Briggs, of a remarkable curve on Southern Pacific R. R., at Tehichipa Pass, California.

The Secretary announced that the usual session of the Drawing School will commence on Monday, Oct. 2, prox., under the direction of Prof. L. M. Haupt: that Mr. D. S. Holman will open a class in Phonography, under the auspices of the Institute, on the same date, and also, that the lectures during the coming winter will consist of two courses of sixteen lectures each, one being elementary lectures on such subjects as are likely to be useful to apprentices and artisans; and the other course, the usual illustrated scientific lectures—one of each course to be given each week, beginning about the first of November. He called attention to the fact that the expenditure by the Institute for these lectures is very large, and appealed to the members to give them the hearty support which they deserved.

Under the head of Deferred Business was taken up the resolutions of Mr. Jones, offered at the May meeting, relating to the adoption of the Majority Report on the Metric System of Weights and Measures, when, on motion, the further consideration of the subject was postponed to the stated meeting in October next.

Mr. Chabot moved that the meeting do now take up the resolution of Mr. Orr, relative to the construction of a ship canal across the great American isthmus, offered at the last meeting, and laid on the table. The motion was lost.

The Secretary read a letter from the Society of Arts of Geneva, Switzerland, accompanying and presenting to the Institute an example of the medal struck in commemoration of the one hundredth anniversary of the foundation of that society. On motion it was

Resolved, That the medal be accepted, and the Secretary be directed to return a proper letter of acknowledgment.

Mr. J. J. Weaver offered the following as an amendment to Art VII, sec. 2, of the By-laws, and it was seconded by Mr. Jas. Eccles: "He shall notify the members of the Institute of the monthly meet-

* See page 226.

ings by postal card, stating the nature of the business to be brought before it."

On motion of Mr. J. J. Weaver it was

Resolved, That we respectfully request the Board of Managers to send notices for each monthly meeting, to all members in good standing.

On motion, the meeting adjourned.

J. B. Knight, *Secretary.*

The Improvement of Hell Gate Channel, New York.—The final explosion at Hallett's Point occurred on Sunday, the 24th inst., at 2.50 P.M., and was an exceedingly successful event. Somewhat more than 50,000 pounds of explosive material, mostly dynamite, were charged; and the explosion of the whole, so far as observation or report was an indication, was nearly instantaneous. At this time the completeness of the explosion has not been fully ascertained, but there is every reason to believe that every portion of the explosive was discharged. Observations over the surface of the water in different directions showed the extent of explosion reached, as indicated by the disturbance and foam, in each direction, out to the limits of the mines. At these limits the water appeared to lift three or four feet, and this lifting seemed over the whole surface, which, after a momentary interval, broke and spurted up in columns, variously estimated at from twelve to twenty feet high, followed by the cloud of black steam which is formed by hot vapor laden with condensed moisture. No report accompanied the explosion—a stifled thud and slight shock to the ground was the sole outward exhibition beyond the disturbance of the water. On the Point itself a wave of water must have run up some eight or ten feet, but the commotion did not extend to neighboring shores, although some of them were not over 1000 feet distant, except as a heavy wash of a foot or two. Not a fragment of rock was thrown out of water, and yet the whole surface of over 100,000 square feet of rock, ten feet in thickness, was lifted, rent and dropped into the mines beneath. No masses of rock were displaced, and as the explosion was timed for slack-water at full tide, no obstruction was made in the regular channel and the navigation of the Sound has not been in the least interrupted. Twelve to fifteen feet of water now exist where the rocks were previously exposed at low tide, and after removal of shattered material there will be twenty-six feet depth at the same

point. The explosion leaves from 80,000 to 90,000 tons of loose rocks to be removed. The accomplishment of this enginering feat without disaster, and with so successful a result, is an enviable record for General Newton, U. S. Engineer, who has charge of the Hell Gate improvement.

Thallene.—A communication to the Editor, from Prof. Henry Morton, President of the Stevens Institute, referring to the article of Doct. Tweddle in the JOURNAL (this volume, page 204), claims that the impression given by Doct. Tweddle's language as to the isolation of the hydro-carbon, to which Prof. Morton gave the appropriate name of Thallene, is in some respects erroneous. Doctor Tweddle wrote: "this substance was examined by Prof. Morton, to whom I sent some for examination." Prof. Morton writes that while he was engaged in 1872 in the study of fluorescent substances, he was furnished by Prof. Horrford, with about two ounces of tarry residuum from petroleum distillate, which residuum he had obtained in Pittsburgh. From this Prof. Morton extracted a gram or two of a gum solid—the quantity was entirely too small for study or analysis. On application to Prof. Horrford for more of the crude distillate "he referred me to Doct. Tweddle, upon whom I called in New York." "I called upon this gentleman, explained what I had done and asked a further supply of the tar, which was then and afterwards promised, but I have never received an atom of the substance from him. Subsequently I obtained an abundant supply from the works of Mr. John Truax, of Pittsburgh (from whom the first tar on which I experimented was derived), with which the researches ending with the isolation of 'Thallene' were made." An account of these researches, descriptive of the methods employed in isolation and of some of the properties of thallene will be found in the *Chemical News*, 1872, Vol. XXVII, p. 272, and in other chemical and philosophical journals of the same date. The investigations of Prof. G. F. Barker, of the University of Pennsylvania, and of Doct. Tieman, of Berlin, indicate, that Thallene has the same composition as Anthracene, viz., C_{14} H_{10} while the chistalline form, solubilities and fusing points, and the chemical combinations with bromine, chlorine, etc., show that it is unlike that body. Prof. Morton objects to the use of the name Thallene as given to a mere product of distillation, by Doct. Tweddle (see page 207) when it has been appropriately associated with a definite separate carbon compound.

Among the exhibits of the Steven's Institute of Technology at the Centennial, Main Building, T 76, will be found the following specimens, the latest of which were prepared by Prof. Morton, two years ago:

No. 1.—Crude thallene, washed with benzine, prepared in 1872.

No. 2.—Crude thallene, washed with benzine and hot alcohol, prepared as above.

No. 3.—Thallene, by repeated crystallization, prepared as above.

No. 4.—Thallene C. P.

No. 5.—Thallene chinone.

No. 6.—Thallene bromide.

No. 7.—Thallene chloride.

No. 8.—Thallene picrate.

No. 9.—Sublimed Thallene.

No. 10.—Solarized Thallene, or petrollucene.

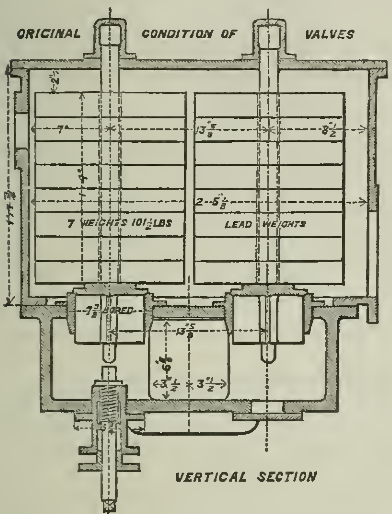
Boiler Explosion on the Thunderer.—Several explosions have quite recently occurred on board English naval vessels, resulting in loss of life, and have called forth some severe criticisms from the leading English engineering journals. The most important of these as regards loss of life and property, and the peculiar circumstances attending it, was that on board the *Thunderer*, which occurred on July 14th, 1876—the explosion of one of eight main boilers with which she was fitted, and resulting in the death of 47 persons.

The *Thunderer* is a twin-screw turret ship, and was built some three years ago, and had made her trial trip, but had not run the measured mile as required to determine her speed, and at the time of the explosion was steamed up for the purpose of making that trial.

The boilers were of the rectangular multitubular type, about 15 feet wide (front), 13 feet high, and 10½ feet deep (length of tube), such as have been in use in the English navy for many years. The explosion carried away nearly the whole of the front top plate, about 15 feet long by 4 feet 3 in. wide.

The evidence shows that the boiler which exploded was fitted with two steam stop-valves, one 10½ in. diameter leading to the main steam pipe and thus connecting with the other boilers, and the other valve, 6 in. diameter, connecting with the auxiliary steam pipe, and also with two safety valves, 5⅞ in. diameter; these four valves being the only outlets for steam.

The safety valves were of the three wing type, with guide spindle, reaching to top of valve box and loaded with lead rings, both being set in one cast iron casing or box, as shown in the illustration.



One valve in each valve box was fitted with a lifting screw underneath, by which it could be lifted so as to relieve the pressure in the boiler. A pipe was attached to the valve box for conducting away the escaping steam in such a manner that it could not be seen in the stoke hole.

This boiler (like all the others) was also fitted with a Bourdon steam gauge, marked to a pressure of 35 lbs., the working pressure being 30 lbs.

At the time of the explosion *both the steam stop valves were closed*, as shown very positively by the evidence; and very little effort seems to have been made to ascertain who was responsible for this blunder.

On the day of the accident, when steam had been raised to 26 lbs. pressure, as indicated by the gauges on the other boilers, and the engines were working slowly, it was observed that the gauge on this one showed *no pressure.* A workman was sent to ascertain what was the difficulty, and was told to break the glass and work the hand, which he did, and the hand rested on the 15 lb. mark. An examination of the gauge after the explosion showed that at a pressure of about 60 lbs., or anything above that amount, the hand would be carried around to the wrong side of the zero pin, and indicate no pressure, but if in the breaking of the glass and working the hand it should accidentally be carried over the pin, the hand would pass on to about the 15 lb. mark, where it would be thrown out of gear and the pressure could be raised to any point, without the gauge indicating more than 15 lbs. Experiments made after the explosion, show that this action did take place in the gauges attached to the other seven boilers, at pressures ranging from 52·94 lbs. to 62·07 lbs.

The safety valve box was bolted to the front plate of the boiler at its top edge, and was, consequently, carried away by the explosion,

and much injured; but a careful examination showed no evidence of its having been tampered with, and both valves turned freely in their seats, although the fit of the wings was very close. It was suspected that the valve might stick from the difference in the expansion of the brass valve and seat and the cast-iron case, and, accordingly, a valve box from one of the other boilers was tested with steam a considerable number of times, when it was found that one of the valves, weighted to 30 lbs. per sq. inch, required from 40 to even 60 lbs. to lift it on first heating, although perfectly free in its seat when cold.

The decision arrived at as to the cause of the explosion is embodied in the following extract from the testimony of Mr. F. J. Bramwell, one of the leading scientific witnesses, and seems to have been acted on by the coroner's jury in forming their verdict of accidental death:

He "could, therefore, only suppose, unlikely as undoubtedly it appears, that both safety valves of the exploded boiler on being first heated as they were from cold water in the boilers, on the morning of the 14th of July, remained stuck down in their seats, and the stop valves being shut there was accumulated that heavy pressure which the bulging of the sides of the smoke box and of other parts of the exploded boiler proves, must have prevailed there; an excessive pressure also consistent with the behavior of the pressure gauge, and with the marks of the spindle of the safety valves."

This difficulty with close fitting safety valves set in iron chambers, has long been known and acted on in this country, but seems not to have been observed in the English navy, although so thoroughly established by experiment after this explosion. The writer has often met with this trouble in the valves of hot water pumps and safety valves, where they were of brass set in iron chambers.

This difficulty may also be developed after several days' use. Each time the valve is heated the brass seat has the tendency to expand more than the iron case or chamber, but is prevented from doing so by the surrounding iron, and is, therefore, slightly compressed in diameter, and after this is repeated several times the permanent reduction may become more than the original clearance of the valve in its seat.

It is quite common for such valve seats to become quite loose, and when not fastened in place otherwise than by the friction of the fit, have been known to adhere to and raise with the valve. K.

Donation of Valuable Books.—As will be seen by the Secretary's report of the Sept. meeting of the Institute, an exceedingly valuable donation of books has been made to the Library by Henry Seybert, Esq. The list in all numbers over 500 works, mostly on chemistry and subjects relating thereto, and forms a valuable addition, greatly adding to the completeness of the Library in essential books of reference. These books formed a portion of the professional collection of the late Dr. Adam Seybert, the father of the donor, and their present deposition will continue their usefulness as an entire collection to succeeding generations. In the changes which years bring in families, it frequently happens that accumulations of technical books of the highest estimation and immediate value to the collector or, generally, to professional men, become of lesser importance to those who remain; and if such collections can be placed where their utility will be demonstrated, as this one has been, they become a memorial of the attainments of a life-time, and at the same time, they continue to be available in the promotion of those interests of science to which they were originally dedicated. This particular selection of books is remarkable from its variety and value, and the acquisition is highly appreciated, as is testified by the thanks of the Institute to Henry Seybert, Esq.

Book Notices.

NOTES ON BUILDING CONSTRUCTION, PART. II. Commencement of second stage or advanced course, arranged to meet the requirements of the Syllabus of the Science and Art Department of the Committee of Council on Education, South Kensington. 8vo, pp. 236. Rivington, London, Oxford and Cambridge. For sale by J. B. Lippincott & Co.

Part I of this work was favorably noticed in the JOURNAL, vol. C, p. 24. This second part is chaptered and paged in sequence with the first part, so that the two parts will together form one volume. In the notice of Part I the reviewer made some exception to it, as exhibiting details of building construction not always of the most approved modern designs or according to the best practice *in this country* but still it was recommended to readers or students as containing in interesting form much useful and important information. This second part goes over little new ground, but simply essays to add further knowledge of details to what had been previously presented under the same head. Most of its contents should properly have been given, if the building processes were to have been shown in relative completeness, in connection with the former part. Admitting the incompleteness of the

first description, the second one would have supplied, at least in part, the deficiencies, although the arrangement of the subjects would be somewhat confused by the supplementary information for chapter I, appearing as chapter XIII. But the defects noticed in Part I in its failure to exhibit modern or even workmanlike practice are exaggerated in Part II. It is desirable that such a book should as a book of reference or of study be above the implication of being useful only to those who know better than to trust to it.

Exceptions here and there to a statement of general or particular character, a failure to exhibit the several methods of manipulation in workmanship, or the choice of possibly not the best method out of several, and the omission of others, might be admissible in a book of this kind; but the preponderance of mistaken information or even its frequency is seriously derogatory to the usefulness of a technical book. As it is, in this second part of notes on building construction, there is scarcely a description of any procedure in building which can be allowed to pass without some objection or qualification.

Take the first subject treated upon: "Brickwork and Masonry." "Compound Walls."

The section of face-brickwork. The uniform practice of face-brickwork to-day, both in this country and in England, is to show a face of stretchers on the entire face front. For heavy warehouses or similar buildings a Flemish bond of alternate header and stretcher is sometimes adopted, and a wall of no great strength results from the intimate connection of the close-jointed front with the full-jointed back work. Such a wall generally bulges out $\frac{1}{4}$ to $\frac{1}{2}$ an inch between the floors of the several stories.

The practical bond of the face with the back of the wall for the usual stretcher front is a *dog-tooth* bond course, every five or seven courses. This is effected by clipping the back corner of the face bricks at both ends—allowing the faces to show as whole stetchers—and laying a course of diagonal bricks (headers) in the back wall, the projecting corners of which lock into the face work. Now this face-brick work is not a sham as might be implied; it is a necessity of economical construction. The body of the wall is built of comparatively inexpensive material—of common bricks and mortar—stability of structure has called for twice or thrice the thickness of wall as compared with its height over what was required to sustain the mere weight of the building. Under these conditions the use of a skin of face-bricks—bricks made with extra care, of extra solidity, laid with the thinnest of joints—the whole comparatively impervious to moisture, becomes a legitimate application of materials.

The notes on splays for window jambs and bonds in corners exhibit a complete want of knowledge of what constitutes good workmanship and are specially calculated to mislead a student. In the splays there is not the slightest objection to having some of the joints at the angles, if these joints are locked or overlaid by a brick with a clipped head on the next course or come within two or three courses; while in the

angles of outside or show brick work, overlapping ends will make bond enough to admit a clipped stretcher next to them if necessary, without use of notched bricks.

The notes on brick arches are not only bad in methods exhibited, but although some qualifications are made in the text, yet they are likely to mislead the student on the subject. Half-brick rings in arches are *never good*, neither are double rings of any number of bricks. Heavy brick arches can only be trusted when built as voussoirs—separate blocks of close laid, cut bonded bricks—except, possibly, by use of hydraulic cement, whose tenacity so approximates to the strength of the bricks that the arch becomes a concrete mass.

Hoop iron band is discussed, and every precaution described to render it ineffective. Hoop iron laid in mortar will *not* rust or decompose. A film of oxide of iron with a silicate of lime may form on the surface of the hoop, but after that the rusting ceases. A piece of hoop iron No. 20 to 22, laid in a joint three feet long, will, after the mortar has well set, part before it can be drawn out. Hoop iron ought not to be heavier than No. 20, so that the brick-mason can cut it with his trowel, and so that it will lay flat in a joint. It should *not* be "tarred, sanded," or otherwise precluded from contact with the mortar. It should *not* be "bent up into joints."

Chimney withes may be built as described, but good work everywhere does not follow such practice. A Flemish bond each third or fifth course with stretchers for the rest is good work.

So much room has been taken in noticing the brick work only. Roofs, Joinery, Stairs, Riveting, Fire-proof Floors, Iron Roofs, Plastering, etc., follow. Of these "notes on building construction," the only thing to be said is that the information given is unreliable in degree; and it would be possible to discuss all or any of them, and exhibit the same deficiency of accurate knowledge. Not only is the information unreliable, but it is incomplete; and for a text book or a hand book incompleteness which is not constantly set forth may be even more dangerous than error.

The work purports to deal with methods and ways of construction, but the attempt at separation of these details for the purposes to which they are supposed to be applied—the establishing an entire distinction between how to do anything and why it is to be done at all—is certain to produce disastrous results. The object which the pupil should have in acquiring the knowledge of how the skilled workman, in the several occupations of building, performs his tasks, what are his materials of work, is that such knowledge shall be available in his practice as a constructor at some subsequent time. If it is pleaded that the pupil is supposed to have acquired, or to be in the act of acquiring, the knowledge of the strength of materials—of the theory of construction—as a supplement to these studies, then there should have been an acknowledgment in the commencement of the Work that it is but a partial view, and *each paragraph* should

have stated where the essential complementary information was to be found. As the two parts now stand, it may be asserted that the student in the advanced course of the Science and Art Department at South Kensington will have much to unlearn, as well as much more to learn, before he becomes proficient as a builder.

THE NEW ENCYCLOPEDIA OF CHEMISTRY. Lippincott & Co., Phila., 1876. Issued in 40 parts (Parts XI to XV now received), at 50 cents each.

The five parts in continuation of those previously noticed (Vol. CI, p. 392), fully sustain the character then given to this new Encyclopedia. Since the time of the original work of Muspratt, no book on chemistry applied to the arts of equal value to this has been published. The practical character of the first book, in exhibiting processes in actual use at the time in the fullest degree, has been maintained in the present work; so that it will become at once an almost indispensable source of reference to the manufacturer or chemist. It should be recognized in chemical processes, as in mechanical ones, change, both of method and of product, is of constant occurrence, so that a description of the best methods or most desirable products of to-day would omit a large portion of a book like this; but, on the other hand, a full record of what was once the best method or product, if much more voluminous, possesses in its extent alone a higher value for other applications than the restricted practice of the moment will afford. All the chemical processes which once gave good results, although they may now be disused, should be considered and weighed in the advancing steps towards new accomplishments. This Encyclopedia of Chemistry, of 1876, is a fifty years' compendium of applied chemistry, as complete as could possibly be expected to the date of its issue.

Cornish Pumping Engines.—From *The Mining Journal*, Sept 9th, 1876.—The number of pumping engines reported for July is 29. They have consumed 2177 tons of coal, and lifted 16,200,000 tons of water 10 fms. high. The average duty of the whole is, therefore, 50,100,000 lbs. lifted 1 ft. high, by the consumption of 112 lbs. of coal. The following engines have exceeded the average duty:

Crenver and Wheal Abraham—Stuart's 90 in.	Millions 55·1
do. do. —Willyam's 70 in.	61·9
West Basset—Thomas' 60 in.	50·2
West Tolgus—Richard's 70 in.	61·7
do. —Taylor's 60 in.	51·3
West Wheal Seton—Harvey's 85 in.	66·2
do —Rule's 70 in.	60·5
Wheal Unity Wood—70 in.	70·0

Civil and Mechanical Engineering.

ISOCHRONOUS GOVERNORS.

By A. K. Mansfield.

The office of a governor or regulator is to prevent deviation from a constant, uniform velocity of the machine governed, within certain limits. That no governor can retain this velocity absolutely constant is generally understood, from the fact that all governors are first called into action after a change of velocity has taken place. The amount of change required to call the governor into action is a measure of its *sensitiveness*. The governor having begun to act, it is in most cases desirable that it should prevent further change of velocity; also that it should restore the *true normal velocity*, and that as quickly as possible. That most governors now used fail to perform these offices as well or as quickly as may be, will appear from the following discussion, which treats, however, of centrifugal governors only, since the majority of governors in use are of this kind, and since this may be considered the type of governors in general.

Fig. 1 is a diagram of a Porter governor, which differs from the ordinary Watt's governor, or revolving pendulum, in having a heavy weight attached to the lower ends of the links. Let G represent the weight of one of the balls, G' the additional weight, l the length of an arm from the point of suspension to the centre of gravity of the ball, l' the length of a link, also of that portion of an arm intercepted by the link, a the distance from the axis to the point of suspension of an arm, also to the points of support of the weight G', a the angle of an arm, also of a link with the axis, and C the centrifugal force of one of the balls when the angular velocity is w. If the governor is in equilibrium, the resultant moment of the forces C, G and $\frac{1}{2}$ G', about the point of suspension, is equal to zero. The moment of C is $C l \cos a$, of G, $- G l \sin a$, and of $\frac{1}{2}$ G', $- \frac{1}{2} G' \frac{l' \cos (90 - 2a)}{\cos a}$, being the com-

ponent in the direction of the link of the vertical force $\frac{1}{2}$ G' times the perpendicular distance of the link from the point of suspension. We have, therefore,

$$C l \cos a - G l \sin a - \tfrac{1}{2} G' \frac{l' \cos (90 - 2 a)}{\cos a} = 0,$$

or, since from mechanics $C = M w^2 r = G \frac{w^2}{g} (l \sin + \mathrm{a})$, (where g = gravity); and $\cos (90 - 2 a) = \sin 2 a = 2 \sin a \cos a$, we have by substitution, and after dividing both members by $G l \sin a$,

$$\frac{w^2}{g}(l \cos a + \mathrm{a} \cot a) = 1 + \frac{G' l'}{G l}.$$

But the quantity in parentheses is the vertical distance of the balls from the intersection of the arm produced, with the axis, which distance we will call h. Writing this in the form of an equation, we have

$$h = l \cos a + \mathrm{a} \cot a \quad . \quad . \quad . \quad . \quad \text{(I)}$$

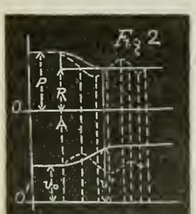
and substituting in above

$$w^2 = \frac{g}{h} \left(1 + \frac{G' l'}{G l}\right) \quad . \quad . \quad . \quad . \quad \text{(II)}$$

This is the equation of equilibrium of the Porter governor. If $G' = 0$, this becomes $w^2 = \frac{g}{h}$, which is the corresponding equation of the Watts governor.

These equations show that different values of h correspond to different values of w; therefore, if the governor is so constructed that h remains constant for all positions of the balls, w will also be constant, and the governor is *isochronous*.

The action of isochronous and non-isochronous governors is shown graphically by Fig. 2. We suppose the governor in each case to be



direct acting, that is, that the vertical movements of the balls are communicated directly to the valve or other regulating apparatus. O is the origin of co-ordinates of the curves of force P and resistance R, acting on any point of the machine designed to move uniformly; and O' is the origin for the curve of velocity of the same point. Horizontal co-ordinates are distances traversed by the point. Suppose the point to have moved uniformly from O to A at its normal velocity v_0, and at A the resistance to be suddenly decreased to R_1. Then, on account of the accelerating force $P - R_1$, the velocity begins to increase, the balls of the governor to rise, the valve to close, and P to de-

crease. This continues until P is reduced to R_1, when the velocity has reached its maximum v_1, and, if the governor is not isochronous, the machine continues to move uniformly at this velocity. If, however, the governor is isochronous, the balls can be in equilibrium at only one velocity v_0; therefore, after P is reduced to R_1, since the velocity is greater than v_0, the balls continue to rise, the valve to close, and P becomes still less, until, on account of the retarding force $R_1—P$, the velocity is again reduced to v_0, when the balls are at their highest position.

Since P is now less than R_1, the velocity continues to decrease, the balls begin to fall, the valve to open, and P to increase. In this way a series of vibrations of velocity on each side of v_0, and of force on each side of R_1, take place, until the normal, uniform velocity is restored. Unless the governor is isochronous, therefore, it does not restore the normal velocity, but only prevents its increase or decrease beyond certain limits, depending on the variations of resistance in the machine.

The maximum change of velocity following any given change of resistance, is also less with the isochronous than with the non-isochronous governor; for in the former case a slight change of velocity causes the balls to move continually farther from their first position, until equilibrium between P and R is restored; while in the latter case a slight change of velocity corresponds to only a slight change in the position of the balls, and, therefore, of the valve.

As before stated, if h is constant for every position of the balls, the governor is isochronous. To make h constant the balls must be guided in a curve, not an arc of a circle, which may be called the curve of isochronism. In case $G' = 0$ this curve is a parabola, but, otherwise, it is a curve having a complicated equation, the co-ordinates of which are a combination of those of a parabola and a circle. To guide the balls in either of these curves necessitates complicated mechanism, which makes the construction impractical. The points of suspension and length of arms may, however, be so chosen that the arcs of circles in which the balls move vertically shall more nearly coincide with the curve of isochronism, than is the case in the ordinary construction of Fig. 1. The best approximation of this kind is made by choosing the length and middle position of the arms, to coincide with the radius of curvature of the curve of isochronism at that point. In this case the points of suspension would be on opposite sides of the axis from the balls, which makes it necessary to

cross the arms. A more convenient construction is that of Dr. R. Pröll,* in which, crossing the arms is obviated by attaching the balls to the links produced beyond their intersections with the arms.

The approximately isochronous construction is, without doubt, the best for *indirect acting* governors, or those which, when the balls are not in their middle position, permit some other mechanism to act on the valve, etc. On account of the lost motion caused by imperfect fitting of the links and levers, which transmit the vertical movements of the balls, their middle position is not absolutely fixed. Within the limits of this lost motion, the governor should be isochronous. This is the case with a well constructed approximately isochronous governor, which for a short distance each side of the actual middle position is, practically, isochronous, but beyond this is non-isochronous.

The advantage of this construction, when indirect acting, over the truly isochronous, will be seen from the following:

The dotted curves of Fig. 2, which illustrate the action of a direct acting isochronous governor, show also the action of indirect acting governors in general. If, however, the indirect acting governor is isochronous, the balls continue to rise after the driving force has been reduced to R_1; or, as long as the velocity is greater than the normal, and reach their highest position when the velocity is again equal to the normal. The action on the valve is, therefore, greatest at this point. In the non-isochronous governor the balls reach their highest position when the velocity is a maximum, and the action on the valve is, as it should be, greatest at the point. It will be seen from this that the approximately isochronous governor combines the advantages of both the other classes when it acts indirectly, but, as shown above, the truly isochronous construction is to be preferred when acting directly.

A truly isochronous governor has been invented by Prof. Rankine,† in which, in place of making h constant, l' (the distance from point of suspension to point of connection of the arm with the link) is made to vary in such a way as to counteract the variation of h. An objection to this arrangement is the resistance to motion, and consequent lack of sensitiveness, caused by the sliding collars at the ends of the links.

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* For a complete discussion of the theory of this ingenious governor, see "Der Civilingenieur," Frieberg, 1872.

† See Rankine's "Mills and Mill-work," § 363.

Still a third method of making centrifugal governors isochronous, is to make G' vary in such a way that it shall, in connection with the weight of the balls, just balance the centrifugal force due to the normal velocity at every position of the balls. This method, invented by the writer, only necessitates a slight alteration of the ordinary non-isochronous construction. It is an approximate method in which, however, the approximation may be made as close as desired. It has, therefore, the advantages of truly and of approximately isochronous governors.

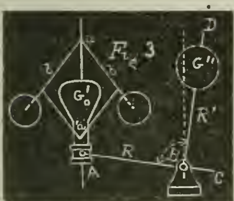


Fig. 3 represents one form of this construction. It consists of an ordinary Porter governor, having the usual lever $A\ B\ C$ to transmit the vertical movements of the balls. This lever has an additional arm $B\ D$, carrying the weight G''. If R represents the length of the arm $A\ B$, R' that of $B\ D$, B the angle between these arms, β the angle between $A\ B$ and the vertical, and F the vertical force at A due to the weight G'', then

$$F = \frac{G''\ R' \sin (B - \beta)}{R \sin \beta} = \frac{G''\ R'}{R} \sin B\ (\cot \beta - \cot B)\ . \quad . \quad (1)$$

To make the governor isochronous, this force must be equal at every position of the balls, to the difference between the actual weight G' and the value that this weight should have at the normal velocity, as found from eq. II; in other words, the resultant of G' and F should vary in such a way as to make the second member of eq. II constant.

G' is the weight corresponding to the height h. If we represent by G'_0 the actual weight, corresponding to the height h^0, of the balls in any particular position, then $G'_0 - G'$ is the value that F should have to make the velocity the same for any other position. Solving eq. II for G', and especially for G'_0, and taking the difference of the equations thus found, we have

$$G'_0 - G' = G \frac{l\ w^2}{l'\ g} (h_0 - h) \quad . \quad . \quad . \quad (2)$$

Noticing the value of the variable h in eq. I, it will be seen that eq. (2) does not vary in the same manner as eq. (1); therefore, F cannot be equal to $G'_0 - G'$ in every position. The best approximation will be made by putting $F = G'_0 - G'$, and $d\ F = d\ (G'_0 - G')$ at the middle position. This gives the following equations :

$$G'' \frac{R'}{R} \sin B (\cot \beta - \cot B) = G \frac{l}{l'} \frac{w^2}{g} (h_0 - h) \quad . \quad . \quad (3)$$

$$G'' \frac{R'}{R} \frac{\sin B}{\sin^2 \beta} d \beta = G \frac{l \, w^2}{l' g} d h \quad . \quad . \quad . \quad (4)$$

Dividing eq. (3) by eq. (4), and assuming $\beta = 90^0$, and $h = h_1$ at the middle position, we have

$$\cot B = -(h_0 - h_1) \frac{d \beta}{d h} \quad . \quad . \quad . \quad (5)$$

and from eq. (4)

$$G'' = \frac{G \, l \, R \, w^2}{g \, l' \, R' \sin B} \cdot \frac{d h}{d \beta} \quad . \quad . \quad . \quad (6)$$

Since the vertical movements of the end A of the arm $A B$ are twice as great as those of the connecting points of the links and arms, therefore the relation between the angles α and β may be expressed as follows:

$$d (R \cos \beta) = -2 \, d (l' \cos \alpha),$$

from which

$$d \beta = -\frac{2 \, l' \sin \alpha \, d \alpha}{R \sin \beta},$$

and from eq. I

$$d h = -l \sin \mathrm{a} \, d \alpha - \frac{\mathrm{a} \, d \alpha}{\sin^2 \alpha}.$$

Substituting these values in equations (5) and (6), remembering that for the middle position $\sin \beta = 1$, and $\alpha = \alpha_1$, these equations become

$$\cot B = -(h_0 - h_1) \frac{2 \, l' \sin^3 \alpha_1}{R (l \sin^3 \alpha_1 + \mathrm{a}} \quad . \quad (\mathrm{III})$$

and

$$G'' = \frac{G \, l \, R^2 \, w^2 (l \sin^3 \alpha_1 + \mathrm{a})}{2 \, g \, l'^2 \, R' \sin B \, \sin^3 \alpha} \quad . \quad . \quad . \quad (\mathrm{IV})$$

We will now distinguish three methods of applying the weight G'', viz., so that the force F is zero (1) near the upper, (2) at the middle, and (3) near the lower position of the balls. In each of the cases we will assume a $= 0$, or the upper and lower joints of the governor to be in the axis, and $\beta = 90°$ for the middle position. The equations for the solution of these cases then become as follows:

$$h = l \cos \alpha \quad . \quad . \quad . \quad . \quad . \quad . \quad (\mathrm{I^a})$$

$$G'_0 = G \frac{l}{l'} \left(\frac{w^2 \, h_0}{g} - 1 \right) \quad . \quad . \quad . \quad (\mathrm{II^a})$$

$$\text{Cot } B = -(h_0 - h_1)\frac{2\,l'}{R\,l} \quad . \quad . \quad . \quad (\text{III}^a)$$

$$G'' = \frac{G}{g}\left(\frac{l}{l'}\right)^2 \frac{R^2\,w^2}{2\,R'\sin B} \quad . \quad . \quad . \quad (\text{IV}^a)$$

The quantity h_0 is that value of h corresponding to the upper, middle or lower position, according as the equations are applied to the 1st, 2d or 3d cases, while h_1 is in all cases the height corresponding to the middle position.

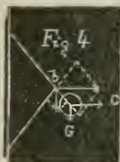
The conditions to be fulfilled to make F vary as $G'_0 - G'$ are expressed in eq. (4). If the above values of $d\,\beta$ and $d\,h$, for the case a = 0, be substituted in this equation, it will be found that the requirement is that $\sin^3\beta$ be a constant. This will be more nearly fulfilled the less the difference between the maximum and minimum values of β, and this difference will be less the greater R. It will be found that when $R = 1{\cdot}5\,l$ to $2\,l$, which is a convenient length the approximation is very close. Since a, when not zero, is usually small compared with l, the approximation is nearly as close in this case.

Case 1.—The force F acts downward in all positions, and, therefore, assists the weight G'_0. This is perhaps the best arrangement for newly-designed governors for ordinary purposes, since the sum of the weights is least.

Case 2.—Since F is zero at the middle position, this arrangement may be applied to governors already constructed. The necked joint at the point of action of F should be made carefully, to prevent lost motion at that point.

Case 3.—F acts upward in every position. This arrangement has a very unique application in delicate machinery, which may be regulated by the variations of the moment of friction at the point of action of F. The energy required of the governor, or the work to be performed by it, in regulating, is here reduced to a minimum. The fulcrum on which the lever turns, may be a knife edge. The point of action of F has a horizontal motion equal to the versed sine of half the arc traversed by that point; but the arm $A\,B$ may be made so long that this motion, and, therefore, the resistance, at that point will be unappreciable. Also, if the construction is carefully made, so that the balls have equal weight and centrifugal force, and the resultant centrifugal force of G' is zero, there will be no pressure of

that weight against the shaft, and the friction at that point will not be appreciable. We have, then, to consider only the resistance at



the four joints of the governor. This resistance is due to the friction caused by the components, in the direction of the links and arms, of the forces C and G. These forces, reduced to the points b b, become $C\frac{l}{l'}$ and $G\frac{l}{l'}$. Representing the sum of the former components by S, and of the latter by S', we have, as may be seen from Fig. 4,

$$S = \frac{C_0\, l}{2\ l' \sin a} + \frac{G\, l}{2\ l' \cos a},$$

$$S' = \frac{C_0\, l}{2\ l' \sin a} - \frac{G\, l}{2\ l' \cos a}.$$

S represents the pressure on the pivots a, and S' that on the pivots a_1 and b b. Let ρ be the common radius of the pivots, and f the co-efficient of friction; and let $C - C_0$ be the increase of centrifugal force necessary to move the balls from their position. This force acts with the lever arm h, while the resistance of friction acts with the arm ρ. The angular motion being twice as great at b as at a and a_1, we have

$$(C - C_0)\, h = \rho f\, (S + 3\, S'),$$

or
$$(M\, w^2\, r - M\, w_0^2\, r)\, h = \rho f \left(\frac{2\, M\, w_0^2\, r\, l}{l' \sin a} - \frac{G\, l}{l' \cos a}\right);$$

reducing, this becomes

$$\frac{w_2 - w_0^2}{2\, w_0^2} = \frac{\rho f}{2\, l' \sin a \cos a} \left(2 - \frac{g}{w_0^2\, h}\right).$$

Dividing numerator and denominator of the first member by $w + w_0$, $2\, w_0$ being considered approximately equal to $w + w_0$; and substituting for $w_0^2\, h$ its value from eq. II, and reducing, this becomes

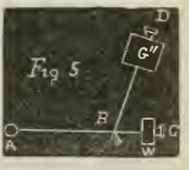
$$\frac{w - w_0}{w_0} = \frac{\rho f}{l' \sin 2a} \left[\frac{2 G'\, l' + G\, l}{G'\, l' + G\, l}\right]. \tag{7}$$

The ratio $(w - w_0) : w_0$ is the coefficient of *lack of sensitiveness* of the governor. This equation shows, therefore, that while the sensitiveness is increased by making ρ and f small, it is also increased by making l' and $\sin\, 2\, a$ large. Sin $2\, a$ is, however, a maximum when $a = 45°$; therefore this angle is the most favorable for the middle position of the balls. The equation also shows that if G' is infinitely small compared with G, the sensitiveness is twice as great as if G is infinitely small compared with G'. The sensitiveness is therefore

greater the less the ratio G' to G, and is a maximum, as far as G' is concerned, when that quantity is zero. In this construction G'_0, or that value of G' corresponding to the lower position of the balls, may be made very small, except when the variations of resistance to be regulated by the governor are too great. A small value of G' corresponds to a small velocity w, and eq. (4) shows that $d\,F$ is proportional to w^2; therefore the less G' the greater the changes in the position of the balls to compensate given changes of resistance in the machine.

The quantities ρ and f will be made very small if pointed pivot screws are used at the joints; and where extreme sensitiveness is required, agate bearings may be employed.

The governor may be adjusted in the manner illustrated by Fig. 5. A movable weight W is placed on the arm $B\,C$, the weight being made about heavy enough to balance the lever, without the weight G'', in the middle position. The virtual weight G'' is the entire weight of the lever, and may, therefore, be considered as concentrated at the resultant centre of gravity of the weights G'', W, and the weight of the arms. Moving the weight W on the arm $B\,C$ therefore changes the angle B, which is the adjustment to satisfy eq. III; and moving the weight G'' on the arm $B\,D$ changes R' so as to satisfy eq. IV.



It is thought that this governor may, in some cases, take the place of the ordinary pendulum with advantage, for variations in the resistance of the atmosphere cannot affect its correct action, variations of temperature can affect it but little, and it may be made almost absolutely isochronous.

Fracture of Fly-Wheel.—The London *Engineer* states that recently a fly-wheel three tons weight, nine feet in diameter, cast in one piece, having worked for years as part of a steam engine, was laid horizontally on two balks of timber in the yard of the West Hartlepool cement works, Eng.; the wheel was left perfect at night, and was found next morning fractured in several places, no person having touched it. The day previous the sun's rays had heated the rim considerably, and the night being cold, the arms having retained but little heat, contracted too rapidly, snapping from the boss and rim of the wheel.

THE MANUFACTURE OF STEEL AND MODE OF WORKING IT.

By D. CHERNOFF, Assistant Manager of the Abouchoff Cast Steel Works, near St. Petersburg. Translated by W. ANDERSON, M. Inst. C.E.

Communication to the RUSSIAN TECHNICAL SOCIETY, 1868.

[From *The Engineer*, July 7th, 1876.]

[Continued from Vol. cii, page 186.]

From what has been said above, you must have perceived that the whole point lies in the structure of the steel, and that for successful forging, the heated ingot, after it is taken out of the furnace, must be forged as quickly as possible, so as to leave no spot untouched by the hammer, no spot in which the steel might crystallize quietly, because, as I have said, the heated piece of steel must be considered in an analogous condition to a saturated solution of strongly crystallizing salt, which, the moment it is allowed to cool quietly developes large crystals. I repeat that this has reference to temperatures higher than *b*.

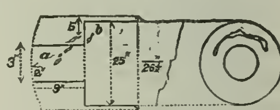
To show you how great is the tendency to crystallization in steel heated up to a high temperature, and allowed to cool quietly, even for a short time, I have brought some specimens by which you can judge of this tendency. The larger specimen was obtained under the following circumstances: An ingot of soft steel prepared for forging was allowed to remain in the furnace for half an hour after it had been heated to a bright orange heat, because the hammer was occupied by another forging. But, in order not to overheat the ingot, the smith reduced the temperature of the furnace, and gradually let down that of the work to a bright red. If you will now call to mind what I have said about the tendency of steel to crystallize in cooling between the temperatures *c* and *b*, you will readily believe that during this half hour the ingot had time to change its internal structure from the amorphous to the crystalline, a change which was greatly assisted by the extreme softening it had undergone at the higher temperature, which presented favorable conditions for the movements of the particles within the mass. As soon as the hammer was at liberty, the ingot was taken out of the furnace, and placed on the anvil; with the very first blow on its middle, the end

of the ingot tumbled off from the effects of the concussion; the form of the fracture you can see on the first specimen before you. The remaining samples are taken from other ingots under similar circumstances, and they all show how strongly the crystals have developed themselves; and, moreover, each crystal seems to have formed itself in an independent manner, with so little cohesion to the neighboring crystals that one shock was sufficient to separate them, and allow the overhanging piece to detach itself by its own weight. The specimens show that fracture has taken place only along the surfaces of the crystals, and nowhere through the body of them.

It might be concluded from the incident above described that the ingot was completely spoiled, and could not be forged again. But such a conclusion would be quite erroneous. It is true that the higher the temperature of the steel, the more susceptible is it to the action of the furnace gases, and the quicker it changes its chemical condition, so that if kept to a high temperature in the furnace it will gradually lose its carbon and be slowly converted into iron, burning. The example I have cited, however, is only a case of overheating; and in order to know how to correct the mistake made, we must turn to the conditions of crystallization.

Let us, again, take the beaker of melted alum. Suppose the melting point to be t_0, and that the solution was further heated up to t_1 under which operation it would continue liquid. Let the temperature fall gradually, keeping the solution perfectly quiet, then we shall find that at some temperature t between t and t_1 the salt will begin to crystallize; but it is only necessary to shake up the solution to make the crystals dissolve again at the same temperature t. We shall notice, also, that there is scarcely any cohesion between the separate crystals so formed, and if we do not wish to disturb their mutual relations, we shall have to allow the crystallizing solution to cool below the temperature t_0, and then by a second heating up to t_0 we should again receive a fluid mass. The same result would be obtained by a simple single increase of temperature; the difference lies in this, that the liquid produced from the destruction of the incipient crystals in the three cases stated has three distinct temperatures. Applying this reasoning to steel, it is easy to see that, in the case cited, the temperature of the ingot should have been raised again before forging, so as to impart to it an amorphous structure; it should then have been quickly and unceas-

ingly forged all over its extent, while the temperature was lowering somewhat, and the tendency to crystallization decreasing. Or the particles that had commenced to crystallize might have been brought into a motion corresponding to the shaking of the beaker, but very carefully, so that the crystals formed should not fall to pieces, in other words, hammered with the very lightest blows; and the temperature being higher than *b*, the crystals would have run into each other, the ingot would have assumed the amorphous condition, after which it might have been worked like a piece of wax. It is, of course, better under such circumstances to allow the overheated ingot to cool quietly, then to heat it again, taking care not to allow the temperature to rise too high and give the mass an opportunity of again changing the restored amorphous condition to a crystallized one; the forging will then not require any special precautions, and the ingot will not tumble to pieces. I now present you with one of many instances of the spoiling of large steel ingots from the causes I have been explaining, and proceeding from a thorough ignorance, on our part, of the material with which we are working.



On cutting off of the end of a shaft 25 in. diameter, the shake *a b* was met with in the position indicated on the sketch. The dotted lines show the form of the forging before the neck was turned. The walls of the cavity were lined with large well-developed crystals, the size of some of which—as you may see by the specimen before you—reached half an inch, and between the large crystals were interposed smaller ones about one-tenth of an inch diameter; the crystals projected only half their height into the cavity, and on breaking the sample at right angles to the crystalline surface, the prolongation of the crystals into the mass of steel could not be traced; the fracture, though crystalline, was of a totally different nature from that forming the surface of the cavity, and similar to that of the mass of the ingot in the same neighborhood. The surface of the wall of the cavity had a clear unoxidized metallic appearance, with a silvery lustre, as you see by the specimen. The ingot out of which this shaft was forged was overheated in the manner I have described, and taken out of the furnace when the crystals had already begun to form. At the first blows of the hammer on its end the part *c* which received the full force of the blow was separated from

the mass on account of the want of cohesion caused by the crystallization, and formed the internal inclined plane *a b*; and as the forging proceeded, the outer layers, being more acted on by the blows, were more extended, and the cavity considerably increased. The fact that on striking the end of an ingot the force of the blow is taken up by the wedge-shaped piece *c* may be easily demonstrated to the eye, because in those places where swelling, compression, or tension follows the blows of a hammer, a dark shade is soon produced by the partial detachment of thin plates of scale. The same result will be arrived at by an analytical investigation of the effect of a blow on *c*. The appearance of the crystallized surface of the specimen is, as you see, completely analogous to that of every other specimen of overheated steel; the difference lies only in this, that the surface is not oxidized because the air could not penetrate into the cavity while the shaft was in a heated state.

It is worthy of remark that if a piece of steel be so greatly overheated as to assume a strongly crystalline structure, and become liable to destruction at the least shock, and is allowed to cool quietly; then the separate crystals, if they have not been separated by external forces while in a heated state, become so joined or grown together that the fracture of the cold piece takes place, not along the surfaces of the separate crystals, but indifferently through their mass, though the junctions of the fractures of individual crystals generally take place along their planes of adhesion, owing to which, such fracture is always very sparkling. From this it is evident that the close contact of two surfaces of metals of the same nature heated to a higher temperature than *b* is sufficient to produce union. This is, in fact, welding; and if, in welding, hammering is always necessary, it is only because, in the first place, it is very difficult, without hammering, to press two pieces one against the other; and, secondly, that it is otherwise difficult to free the surfaces to be welded from the slag which alone protects them from oxidation during the heat. Of course the more homogeneous or analogous the structure of the two pieces the more perfect will be the union; but one of the first conditions is that there should be the fullest contact between the unoxidized metallic surfaces.

Up to the present we have been discussing the forging of steel only at temperatures higher than the point *b*, and we have stated that the aim of the forge-master must be to change the form of his ingot in

such manner as to keep all its particles in constant motion, and so hinder the formation of crystals, which materially lower the tenacity of the steel. Let us now see what circumstances arise in forging below the temperature *b*. The fracture of a piece of cast steel presents a rough surface consisting of groups, as it were, of crystalline *débris*—so-called grains—piled one on another, and generally of a very irregular form. Under the microscope it is easy to see considerable interstices between the groups of grains, and, on more minute examination, spaces may be observed between the grains themselves, which form with each other various interlacings and combinations. In a word, steel, under the microscope, has a more or less porous structure, at first sight, destructive of any belief in the tenacity ascribed to it. Time will not permit me to enter into details relating to the appearance, size, and arrangement of the grains; it answers my purpose simply to direct attention to the fact that among the grains of steel there are numerous vacant spaces—pores. The question arises—what becomes of these pores when the steel, being heated up to the temperature *b*, acquires the amorphous condition? In all probability, during the rise of temperature from *o* to *b*, the expansion of each individual grain, formerly in itself a compact body, goes on incomparably faster than the increase of the external dimensions of the piece of steel, so that the period at which it assumes the amorphous condition coincides with the moment when the atoms composing the individual grains, moving away from each other under the influence of heat, fill up these spaces; it is, therefore, conceivable why steel becomes at this stage incompressible—why it is impossible to increase its density by hammering, no matter how heavy the blow may be.

It is evident, from the above reasoning, that if we wish to increase the density of steel, to approach its component grains to each other and so bring them to a more energetic cohesion, we must do so when not opposed by the force of heat, that is only at temperatures below the point *b*. Thus, forging at temperatures below the amorphous condition has the important advantages we are in the habit of ascribing to it. We never forge large ingots below the temperature of amorphous structure, and guns never were and never are forged below that point, because for gun steel, the temperature of amorphous structure lies, as I have already stated, at a dull red heat, that is, within limits below which, we can produce no effect on large steel masses, with the mechanical means at our disposal. It

would be necessary to forge small ingots under our largest hammers, and what an exhibition of inadequate mechanical appliances would be presented if a 4-pounder gun were forged under a 35 ton hammer! The practice now is to forge the 4-pounders under the 3-ton, and sometimes the 5-ton hammer, while the 35-ton hammer is used for the 6 in., 8 in., and 9 in. guns, in which the diameter of the cast ingot reaches up to 40 in.; but if you picture to yourself such a large mass of steel heated to a non-sparkling red heat, you will perceive that the utmost efforts of the heaviest hammer will remain inoperative—it would be impossible to forge it. Forging is carried on at points below the amorphous condition, but it is only in very small pieces, and by those who have some knowledge of the influence of heat on steel.

FIG. 2

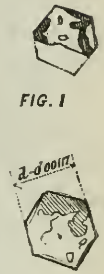


FIG. 1

Fig. 1.—Crystals taken from the sides of a cavity in steel ingot formed by contraction—magnified 275 times.

Fig. 2.—Groups of crystals taken from the sides of a cavity formed by contraction in a cast steel ingot—magnified 275 times.

If a cast ingot of any given structure is heated not higher than the point *b*, then in its heated state it will retain its structure. If it was crystalline, then in a heated state it would be composed of the same crystals, which, however, would be considerably softened. If the piece of steel be forged in this condition, then its crystals or grains, being driven against each other, will change their shapes, becoming elongated in one direction and contracted in another, and the increase of density becomes so considerable that I have found the specific gravity rise as high as eight, which I have never yet found in steel forged at temperatures higher than *b*. This comparatively cold forging communicates to the metal great clearness of ring, it is no longer so easily worked with the file, weak sulphuric acid produces hardly any effect on it, and so on. With regard to its absolute tensile strength, I regret very much that I have been unable to make any experiments; but there can be no doubt that it is very high. The fracture of such

FIG. 3

Appearance of a transparent substance that crystallizes in six-sides plates on the surface of cavities formed by contraction in steel ingots—magnified 82 times.

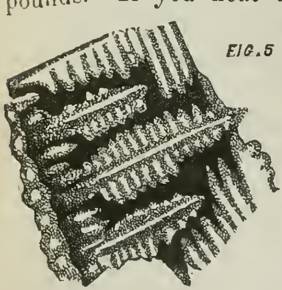
steel has a silky lustre, and under the microscope it is very difficult to trace the limits of the individual grains; they present the appearance of waxy little balls squeezed together under a powerful press. If you cut off and polish the surface of a piece of steel so treated, and then immerse it in weak sulphuric acid, after a time a pattern will form on the surface, which presents the appearance of an irregular interlacing of crooked lines, the size of the network depending on the original size of the crystals, the manner of forging, and so on. I have already stated that the tendency to crystallization, as well as the form of the crystals and their relative positions, depends on the purity of the steel, and the conditions under which the cast ingots are poured and cooled. In the higher qualities of boulat, the tracery developed by acid is of remarkable beauty and regularity.

The cause of the patterns appearing is the various groupings of the crystals during their formation. These crystals have not the same chemical composition; the lighter parts of the tracery contain much more carbon than the darker parts—a fact which I have demonstrated—and consequently, simultaneously with the grouping of the crystals or grains, there is a segregation of like chemical compounds. If you heat the piece of steel thus marked—damascened—up to the temperature *b*, or a little higher, and allow it to cool again, you will no longer be able to obtain any pattern by the action of acids. From what has been already said, the cause of this must be quite plain, and I need not dwell on it any longer. In conclusion, I will show in what manner the properties of a cast steel ingot may be best taken advantage of. With respect to forging at temperatures below the amorphous condition, we can only, as I have already stated, make the smallest guns under the largest hammers. We have at present no mechanism capable of dealing with large masses at low temperatures; but if it were possible, there can

FIG. 4

Arborescent growth on the sides of cavity formed by gas on contraction in cast steel ingot—magnified 80 times.

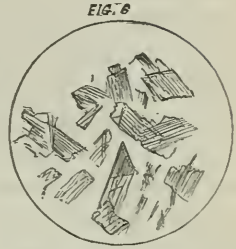
FIG. 5



Crystals on the surface of a contraction cavity in the heart of a 72 lb. cast steel ingot--magnified 82 times.

be no doubt that guns so forged would be of the very best quality, and their reception into the service would be facilitated by the appearance of the patterns brought out by weak acids, because of the close connection which exists between the quality and the appearance of the steel so treated.

FIG. 6



Insoluble substance remaining after dissolving steel in nitric acid—magnified 77 times.

FIG. 7

Two grains from the fracture of an ingot of cast steel 1 in. forged diameter of 0·027 in.—Magnified 150 times.

To adapt ourselves to the means possessed by our steel works, we must strive to obtain our material as much as possible of a fine-gained structure; and with this view it is necessary, as we have already seen, to heat the ingots to a high temperature, and to keep forging them until they cool down below the temperature b, because, by so doing, we shall be giving the work the required form, and at the same time prevent its structure becoming crystalline, but rather make it approach the amorphous condition. But if we examine the circumstances attending the practical application of this rule to the forging of ingots intended for heavy guns, we shall find that, in many cases, it will be impossible to carry it out, and a forging will be obtained, the structure of which is far from uniform, and more likely to be coarse crystalline than fine-grained. We shall attain our object more easily, and with more certainty, if after having given the forging the desired shape, we alter its structure to the homogeneous amorphous condition by heating it, and then fix that condition by rapid cooling to a temperature lower than b. For this purpose, it is of course necessary to surround the ingot after heating by some rapidly cooling medium.

From what has been said above, it is evident that, with the same rate of cooling, we shall fix the amorphous condition of the steel with the greatest certainty when we exceed the temperature b as little as possible; and for that reason it is well to determine that temperature for each ingot beforehand. Having, therefore, heated the finished forging, or better still, the rough turned and bored gun, to a temperature somewhat higher than b—a point which ought to be determined by the pyrometer—let it then be plunged as quickly as possible into the cooling medium, be it water, oil, or what not, and having reduced

the temperature of the work to below the point *b*, allow it to finish cooling gradually, so as to prevent, as far as possible, internal strains due to sudden and unequal contraction. To show you what changes may be produced in the structure of steel by the operations described, I lay before you three specimens. They are all broken from the same piece of steel. The first specimen exhibits the coarsely crystalline, porous structure that characterized the ingot, notwithstanding that it was well worked under the 35-ton hammer. The second sample was heated to a little above a bright red non-sparkling heat, and then allowed to cool in the open air. Comparing the fractures of these two pieces, you perceive the structure is totally different, though offering one surface to the other proves by the fit that the two pieces were at one time united, and that neither piece has been touched by the hammer since they were broken asunder. The third fragment of the same piece was heated to a bright red heat, and then quickly plunged into water, and left till the temperature sank to a reddish-brown heat; it was then taken out and allowed to cool in the open air. The fracture shows that on the external surfaces, for a depth of 0·1 in. the amorphous condition has been completely preserved. In the centre of the piece the mean diameter of the grains, as measured by the microscope, is 0·0004 in., while the mean diameter in t..e first piece was 0·15 in., and in the second 0·005 in. To this I may add that to break the first piece one blow of a hand-hammer was sufficient, to break the second required five such blows, and the third piece had to be broken under a steam-hammer, because the strength of the smith was inadequate for the work.

A similar experiment was made with the tire of a railway wagon wheel. A piece of an ordinary tire was broken by a 5-ton hammer into three pieces. One of them was heated to a light red, and then thrown on the floor to cool in the open air to the ordinary temperature. It was then put under the 5-ton hammer, and required four heavy blows to break it, whereas the first piece broke under one blow of the same hammer. The third piece I heated to a bright red heat, plunged it quickly into water, and took it out again when cooled to a reddish-brown heat, and then found that it required five heavy blows of the 5-ton hammer to break it. Therefore, I say, that in order to fix the amorphous condition, and thereby to increase the tenacity of steel, it is necessary to plunge it, after heating, into water. It may be cooled in oil, but, in the first place, this is expensive, and, in the

next, numerous precautions have to be taken to prevent the oil catching fire. With respect to cooling in water, I must add that the conductivity of hot metal is very small, and that although the external visible parts soon show the desired fall of temperature, yet the central portions remain very much hotter; it, therefore, requires care, experience, and many precautions to avoid the too rapid cooling of the outer layers, and the consequent development of severe internal strains. Time will not permit me to treat this subject in greater detail. I can only state my opinion that not only should every gun be subjected to treatment above described, but also every article made of steel, as, for example, tires, axles, shafts, etc.*

It follows, from the principles laid down, that any steel article having, from constant work and concussion, lost its original strength, that is, assumed a crystalline structure, as happens to wagon axles, engine shafts, etc., can, by the help of the process above described, be completely restored by having communicated to it, if not an amorphous structure, at least one so finely grained as to be nearly equal to it, and, at the same time, a compactness and tenacity it very likely did not possess when newly taken into service. I trust that you will now find it easy to understand the circumstances and facts which I brought under your notice at the commencement of this paper. I have heard with pleasure, from a friend just returned from England, that at the Woolwich Arsenal they have adopted the practice of heating their steel gun linings, after forging and rough turning, and plunging them into oil; he was unable to give me any details of the operation, as he only noticed it in passing, but the object of the treatment was, he ascertained, to give the steel greater tenacity. It is possible that I may soon obtain information as to the reasoning which led to the adoption of this practice, and I shall be exceedingly pleased if I find it is based on theories similar to those I have had the honor of laying before you this day. With respect to the doctrines I have been advocating, I have been accused of being too bold in my conclusions, but I am prepared to take a still more decisive step, and to announce the opinion, resulting from my observations, that "future investigation into the question of forging steel will not deviate from the path into which we have this day directed it."

* 1875. A wagon axle treated in the above manner, and cooled in water, withstood twenty-two blows of ½ ton weight falling 14 ft , and remained unbroken.

APPENDIX.

The following notes of microscopical observations have never yet been published. The drawings annexed were made under the microscope, with the assistance of Hartnack's camera lucida, in the years 1868 and 1869. Figs. 1, 2, and 3 are especially remarkable. They represent the efflorescence appearing in the cavities of hard tool steel, melted in a crucible, and allowed to cool extremely slowly in its furnace. The ingot on cooling exhibited cavities caused by contraction and by bubbles, and these have on their walls or faces arborescent growths, and on the surfaces of these growths I found microscopic crystals, composed of extremely thin transparent plates, having a high refractive power, and extremely hard, so that they scratched glass. The regular hexagonal form of these crystals led me first to suppose that they belonged to the regular hexagonal system; but on passing polarized light through them I was unable to detect any traces of polarizing power, and I am inclined to think, therefore, that these crystals belong to the regular system, and present the very common case of the distortion of the regular octahedron by the abnormal development of two of its opposite sides, by which a regular hexagonal plate may be produced. Similar distortion is frequently observable in alum and nitrate of lead. What this substance may be I am unable to state. I was able to collect but a very small quantity, and that under the microscope, with the aid of a needle. I have the specimens still sealed between glass plates, and I would gladly intrust them to any one who would undertake the analysis. Fig. 1 represents one such crystal, which cost two entire days' labor to secure, because it was necessary to suppress breathing while fishing for it, as the least current of air would blow it from the needle's point, and then it would be most difficult to find again. The crystals seldom occur isolated, but for the most part in groups, as in Fig. 2. In the places marked *a*, *d*, *h*, the crystals are heaped several deep, and of very indistinct and irregular form. In the spots *b*, *c*, *e*, *g*, on the other hand, there is but one layer, and it is clearly seen that they are six-sided plates. The dimensions given in Fig. 1 show how small the crystals are, but their thinness is still more remarkable, because, under a magnifying power of 550, it was impossible to measure their thickness. Fig. 3 represents a portion of the surface of the growth on the walls of the honeycombs, and on this is seen a kind of sweat or stream of a transparent substance, which may be the same as that which has been

spoken of above, or may be different; it is not easy to determine. Fig. 4 represents the form of cavities caused by contraction or bubbles, in which I have often found the six-sided plates. Fig. 5 represents the appearance of the growths occurring in the central contraction cavities of cast ingots of hard steel. All these growths appear to have a smooth polished surface like that of a looking-glass. Fig. 6 represents the residuum remaining after dissolving steel in weak nitric acid. The substance remaining is probably silica; it is of a yellowish-brown color. The particles have the appearance of little plates, and a general appearance similar to the fracture of the steel dissolved. The study of such residuum is extremely interesting, and may lead to the elucidation of many problems concerning the structure of steel. Fig. 7 represents two grains appearing in the fracture of well-crystallized hard cast and unforged steel.

THE HISTORY OF THE STEAM ENGINE IN AMERICA.

The chronicle of the steam engine in this country has received from two sources, some valuable additions which have proceeded from the Centennial Exhibition. The first of these is a letter written by Judge Joseph P. Bradley (U. S. Supreme Court), which accompanies the exhibit of a portion of the cylinder casting of a Newcomen Engine, which is stated to have been in use in 1753 near Newark, N. J. And the second source is a paper written, and illustrated by drawings, by Fred. Graff, C.E., descriptive of the Engines and Boilers for the Water Works of Philadelphia, from the commencement of the water supply in this city in the year 1800, down to the year 1822. The previous reliable information which we have possessed as to the early use of the steam engine before the year 1803, has been founded on a "First" Report of Benjamin Henry Latrobe, member of the American Philosophical Society of Philadelphia, at the meeting of the Society, May 20th, 1803, and published in their transactions, vol. vi (1809 on the title page), in answer to the inquiry of the Society of Rotterdam, "Whether any, and what improvements have been made in the construction of Steam Engines in America?" [The second report does not appear to have been made at all.] By collating and grouping together the data afforded by these several authorities, with

some little additions from general history, an intelligible account may now be presented.

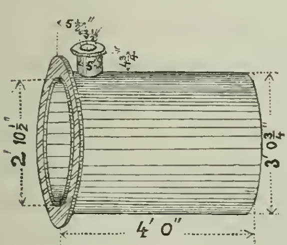
The report of Mr. Latrobe gives the priority of erection of an engine to that at the Schuyler copper mine on the eastern bank of the river Passaic, a few miles above Newark, New Jersey. This engine is the one referred to in Judge Bradley's letter. It was built by the Hornblowers, and one of the sons came to this country with it, and is of peculiar interest as being the production of the celebrated engineers, who were identified with the construction of the first practical engine ever built.

The family of Hornblower went through three generations as steam engine builders, and the recurrence of the name seems, now, not a little confusing to the reader of history. The earliest record is that of Joseph Hornblower, of Bromsgrove, Worcestershire, near Birmingham, who, in 1712, was an engine builder in Wolverhampton; and thirteen years later, in 1725, he left Staffordshire and went to near Redruth in Cornwall, and superintended (probably built) the engine at Wheal Rose mine. There were but two engines in Cornwall in 1720, one finished that year, and one built, prior, in 1714, and the Wheal Rose engine was probably the third. Joseph Hornblower had two sons, Jonathan and Josiah (if not others), who followed the business of the father. According to Judge Bradley, this American Engine was the production of their hands, about the year 1750, (possibly the father yet continued in active business); "and Josiah Hornblower, then in his twenty-fifth year, came to this country with it." "Mr. Hornblower expected to return as soon as the engine was in successful operation. But the proprietor of the mine (Col. Schuyler) induced him to remain, and within the time of two years he married Miss Kingsland, whose father owned a large plantation adjoining that of Col. Schuyler. The late Chief Justice Hornblower, of New Jersey, was the youngest of a large family of children, who resulted from this marriage."

Jonathan, the brother of Josiah, continued as an engine builder in Cornwall, and in 1770, Smeaton names the principal makers of the atmospheric engine as Jonathan Hornblower the elder, and John Nancarrow. [John Nancarrow subsequently came to this country and his descendants are yet resident in Philadelphia.] Jonathan had a numerous family of children, all brought up as engine builders and engine men.

Jonathan, Jesse, Jethro, Jabez Carter (the order of age not being certain), with possibly others, constituted the male portion of Jonathan the elder's children. The family were one and all possessed of high mechanical ability, and under ordinary circumstances would have thriven in their occupation. Their education from childhood had befitted them for leaders of men—directors of work, but on reaching the age when their talent would have been most productive of results, they found the patents of Watt had closed every door of entrance upon engine construction on them. The very constructive ability, manipulations, and implements which the family had evolved in half a century of intelligent labor, was absorbed with their business into the workshop of Boulton and Watt, while for themselves there was neither tolerance nor endurance, as foremen or workmen, in engine construction. Jonathan here named was the inventor and patentee of the compound engine, the history of which in the lawsuits with Watt is well known and subsequently he is said to have been an esteemed engineer of mines in Cornwall, and died 1812-13.

Jabez Carter was the writer of the history of the steam engine for the "Mechanics for Practical Men," of Doct. Olinthus Gregory, which history appeared complete in the first edition only, being partly suppressed in the subsequent editions, not without Doct. Gregory's protest. He died 1814, and with him the prominent connection of the family with the steam engine, after 100 years, appears to have ceased.



There will be found as the exhibit of David M. Meeker, Esq., of Newark, N. J., in the Machinery Hall, column B, 76, a cylindrical casting as shown on the accompanying sketch, which has been prepared to the scale of one-half an inch to the foot. Together with this casting there is the descriptive letter of Judge Bradley. It is a portion of the cylinder with the lower flange remaining upon it, while the upper end has been cut off, apparently in the lathe, as the edge is very straight and true. The interior surface is tolerably cylindrical and straight, with a few recesses, of perhaps an inch in one (the longest) direction across, and less than a sixteenth in depth, but the surface is otherwise generally even. It has been completely scaled by rust since it was in use, although now showing a coat-

ing of paint on evidently clean but much pitted iron. The rusting has effectually removed all indications of wear, so that it presents no marks of former work, and its identification as a "*relic*" at all, rests upon its traditional authentication. There are 12 bolt holes of $1\frac{3}{8}$ inches diameter, equally spaced, in the lower flange—these holes were originally cast in the flange—not drilled. The nozzle (which has its flange broken off irregularly) was probably the injection nozzle, and the steam, drain and snift openings must have been in the bottom casting, an arrangement shown in drawings of Newcomen's engines, as of not unusual occurrence. This description of the casting is given with so much detail, rather for record with the facts presented by Judge Bradley, than for the instruction to be derived from the relic itself. If the usual proportions of Newcomen's engines were followed in this case, there must have been about two and a half feet more length for the cylinder, with a square flange near to the place where the cut was made. This supposition would make the original engine, about 6 feet stroke by 2 feet $10\frac{1}{2}$ inches diameter.

Crude and imperfect as these Newcomen engines are popularly regarded, they have done in their day a great deal of work, and a few of them are yet to be found, not merely as neglected relics, but actually at work at the present time as they have continued to work for a century or more, in parts of England. In Dudley, South Staffordshire, near Birmingham, one instance is quoted to the writer of this article by Mr. J. C. Hoadley, of Lawrence, Mass., of an engine he saw running as recently as the year 1863.

Quoting Judge Bradley's letter to Mr. Meeker: "The steam engine of which you possess a relic was, as you suppose, the first ever erected on this continent. It was imported from England, in the year 1753, by Col. John Schuyler, for the purpose of pumping water from his copper mine opposite Belleville, near Newark, New Jersey. The mine was rich in ore, but had been worked as deep as hand and horse power could clear it of water. Col. Schuyler, having heard of the success with which steam engines (then called fire engines) were used in the mines of Cornwall, determined to have one in his mine. He accordingly requested his London correspondents to procure an engine, and to send out with it an engineer capable of putting it up and in operation.

"After 1760 the Schuyler mine was worked for several years by Mr. Hornblower himself. The approach of the war, in 1775, caused

the operations to cease. Work was resumed, however, in 1792, and was carried on for several years by successive parties. It finally ceased altogether early in this century, and the old engine was broken up and the materials disposed of. The boiler, a large copper cylinder, standing upright, eight or ten feet high, and as much in diameter, with a flat bottom and a dome-shaped top, was carried to Philadelphia. The relic in your possession was a portion of the cylinder, and was purchased by some person in Newark.

"In 1864, I met an old man named John Van Emburgh, then a hundred years old, who had worked on the engine when it was in operation in 1792. He described it very minutely and, I doubt not, accurately. It is from his description that I happened to know the kind of engine it was; although, from the date of its construction, and the use to which it was put, there could have been but little doubt on the subject."

Passing from this authenticated example of an engine, the next reference beyond question is that of Mr. Latrobe (which reference is used by Mr. Graff for some of his assertions). Mr. Latrobe says: "Steam engines on the old construction were introduced in America above 40 years ago. Two, I believe, were put up in New England before the revolutionary war, and one (which I have seen) at the copper-mine on the river Passaic, in New Jersey, known by the name of the Schuyler mine. All the principal parts of these engines were imported from England. With the Schuyler mine engine, Mr. Hornblower, the uncle of the younger Hornblower, came to America. He put up the engine, which at different times has been at work during the last thirty years, and which, notwithstanding its imperfect construction, and the faulty boring of its cylinder, effectually drained the mine.

"The only engines of any considerable power, which as far as I know, are now at work in America are the following: 1st, at New York, belonging to the Manhattan Water-Company, for the supply of the city with water. The Manhattan Company's engine is upon the principle of Boulton and Watt's double engine without any variation. It has two boilers, one a wooden one upon the construction of that first put up in Philadelphia, the other of sheet iron on Boulton and Watt's construction. The fly wheel is driven by a sun and planet motion and the shaft works three small pumps with common cranks.

"2d, one at New York, belonging to Mr. Roosevelt, employed to saw timber. [Mr. Latrobe gives no intelligible description of this engine.]

"3d, two at Philadelphia, belonging to the corporation of the city, for the supply of the city with water; one of which also drives a rolling and slitting mill. [There is no description given by Mr. Latrobe of these engines.]

"4th, one at Boston, of which I am only generally informed, employed in some manufacture."

Mr. Latrobe then adds that in his second report (never given), he proposed to describe some improvements made on an engine erected in New York... if it be found to answer the intended purpose: "Nor ought I to omit the mention of a small engine, erected by Mr. Oliver Evans, as an experiment, with which he grinds Plaister of Paris; nor the steam-wheel of Mr. Briggs."

Mr. Graff's narration now supplies a good description of the Philadelphia water works engine, and is accompanied with drawings.

These drawings of Mr. Graff are derived from the papers of his father. The senior Frederick Graff was engaged as draughtsman for the Philadelphia Water Works in 1799. These Water Works when first built had B. Henry Latrobe as engineer, John Davis as clerk of works and Fred'k Graff, draughtsman. Mr. Latrobe's connection ceased with the erection in 1801 (or 1803 at the furthest), his agreement requiring him to direct their completion. They then remained in charge of John Davis; but in 1805 Mr. Davis went to Baltimore, and Mr. Graff, who had been actively employed in an official capacity upon the Water Works until that time, became Superintendent. He remained in charge until his death in 1847, when he was succeeded as engineer of the works, by his son, the present writer.

The construction of the first engines for the Philadelphia water works were commenced in the year 1800. They were built at the Soho works of Mr. Nicholas J. Roosevelt. The Soho works were situated on Second River, three quarters of a mile west (or N. W.) of the Passaic (the Schuyler mine was on the opposite side of the Passaic, quite near this place). The location will now be found in Belleville or Bloomfield, about four miles from Newark. Messrs. Smallman and Staudinger appear in the transaction, according to Mr. Latrobe, to have been the mechanics; and Mr. Roosevelt the capitalist and owner of works, or foundry.

Mr. Graff gives the following extract taken from the minutes of the committee on water works, dated July 4, 1800; being a report made by Thomas P. Cope, Esq., who was sent to examine the work upon the engines erecting at the time: this extract will give a good idea of the progress of steam engineering at that time, and serve as a measure of the advance made since:

"Took passage (from Philadelphia) in the stage for Soho Works, near Newark, New Jersey, on the morning of the 3d of July, 1800; and arrived there about noon of the next day.

"Soho is named after the works of Boulton and Watt, in England, and is situated about three-quarters of a mile northwest of the Passaic, on a small stream called Second River.

"The works consist of a smith-shop 90x40 feet, with six fires and two air furnaces; next to this is a room 30x20, in which is the fire, for heavy work; four wooden bellows play into a regulator 15x15 feet, with pipes to the forge, and four furnaces for melting and refining copper. Then there is a stone building 20x24, two stories high, with six stampers for preparing loam for the furnaces; next to this is a fitting shop with large lathe and drilling machine, and a water-wheel 20 feet diameter, to bore cannon; next to this is a shop with a water-wheel 30 feet diameter for boring large cylinders; this is now boring a small cylinder for a steamboat, which belongs to Roosevelt, Chancellor Livingston, and others.

"Higher up the stream is the furnaces, 60x50 feet, with two air furnaces capable of melting 40 cwt. of metal each, two blast furnaces for melting and refining copper, with a coal house and pattern shop, with two foot lathes; all are stone buildings; the stream affords a head and fall of 16 to 18 feet.

"The large cylinder for the engine to be used on the banks of the Schuylkill at the water works was cast in two pieces, and united by copper, the joint being secured externally by a strong band of cast-iron, eighteen inches broad, weighing 1,200 pounds. Seven thousand five hundredweight of metal was used for the cylinder; it is six and one-half feet long, and about thirty-eight and one-quarter inches in the bore; about $\frac{3}{4}$-inch throughout was at first to be cut away; one-half inch has been accomplished; two men are required; one almost lives in the cylinder, with a hammer in hand to keep things in order, and attend to the steelings (cutters); the other attends the frame on which the cylinder rests, which is moved by suitable machinery; these

hands are relieved, and the work goes on day and night; one man is also employed to grind the steelings; the work is stopped at dinner time, but this is thought no disadvantage, as to bore constantly the cylinder would become too much heated; the work also stands whilst the steelings are being changed, which required about ten minutes' time, and in ten minutes' more work they were dull again; I examined some of them and found them worn an eighth of an inch in that time. Three of these steelings (or cutters), about three and one-half inches on the edge, are fixed in the head piece at one time. The head piece is a little less than the diameter of the cylinder, and six inches thick, secured upon a rod of iron eight inches in diameter, which forms the shaft of a water wheel.

"The workmen state that the boring was commenced on the ninth of April, and had been going on ever since, three months, and about six weeks more will be required to finish it.

"The wrought iron for the flue of the boiler over the fire will be imported from England, and is in sheets 38 by 32 inches. That yet made in this country is clumsy stuff of different sizes, the largest being 36 by 18 inches, with rough edges which have to be cut smooth by the purchaser.

"July 4, 1800. Signed (Thos. P. Cope)."

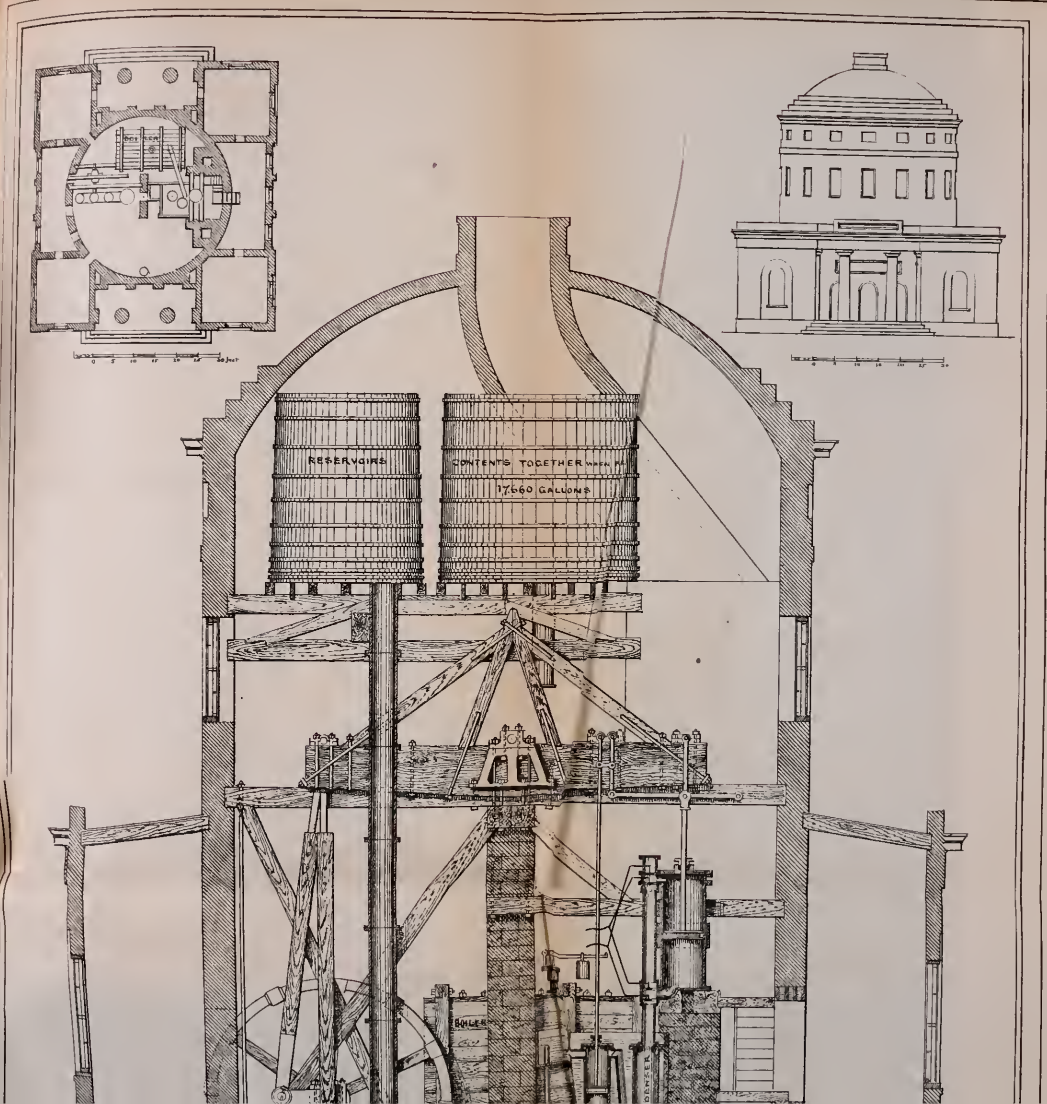
The engine for which the above described cylinder was being made was that put up at the water works on the Schuylkill, at the foot of Chestnut Street.

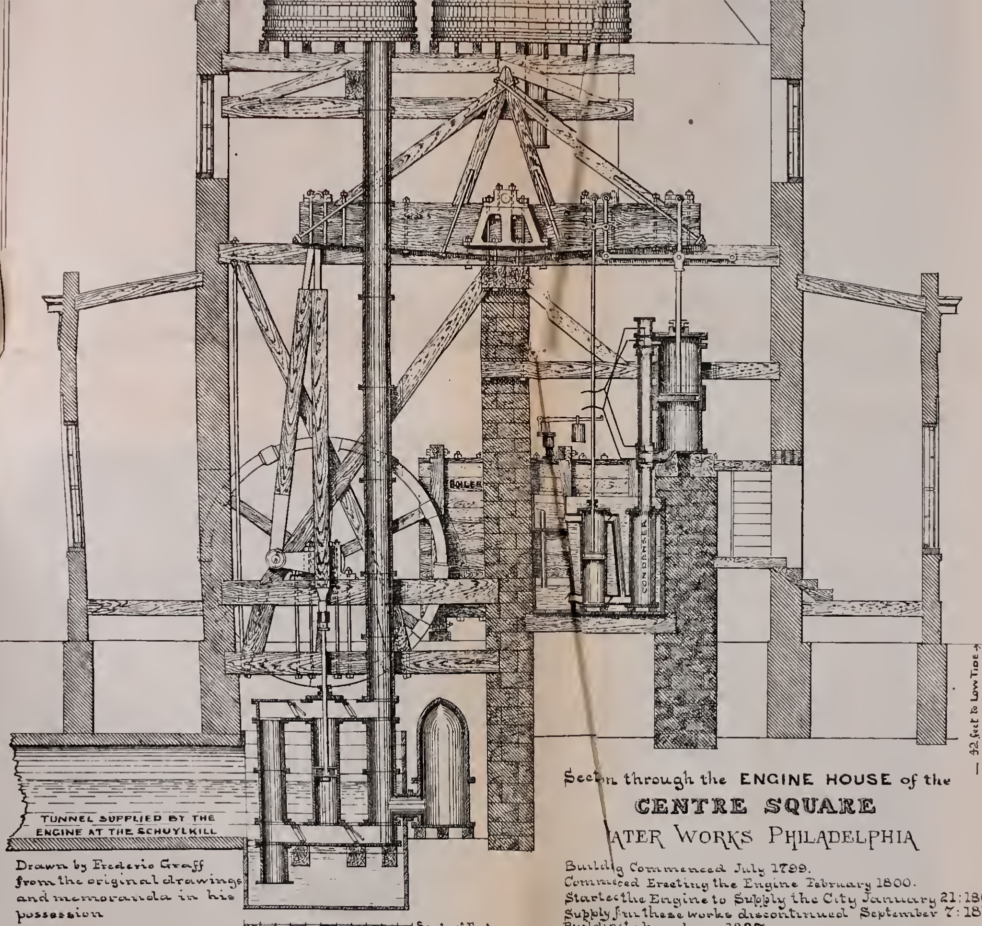
"The cylinder was $38\frac{1}{2}$ inches diameter and six-feet stroke, and drove a double acting pump $17\frac{1}{2}$ inches in diameter and six feet stroke."

"The engine, at Centre square, built about the same time, and at the same place, had a steam cylinder 32 inches diameter and six feet stroke, and worked a double acting pump of 18 inches diameter and six feet stroke, raising the water into tanks about 51 feet high."

"In both these engines the lever beams, the arms and shafts of the fly wheels, the bearings upon which the fly wheels were supported, the hot wells, the hot and cold water pumps, the cold water cistern, and even the external shell or outside of the steam boilers, were all made of wood."

"The boilers were rectangular chests, made of white pine planks five inches thick; they were nine feet square inside at the ends, and fourteen feet long in the clear; braced upon the sides, top, and bottom


BOILER
0 5 10 15 20 25 30 feet
RESERVOIRS
CONTENTS TOGETHER WHEN FULL
17,660 GALLONS
BOILER
CONDENSER



Section through the ENGINE HOUSE of the
CENTRE SQUARE
WATER WORKS PHILADELPHIA

Building Commenced July 1799.
Commenced Erecting the Engine February 1800.
Started the Engine to Supply the City January 21: 1801
Supply from these works discontinued September 7: 1815.
Building taken down 1827

Drawn by Frederic Graff from the original drawings and memoranda in his possession

PHOTO-ZINCOGRAPH, by F. A. WENDEROTH & CO. 1329 Chestnut Street, Phila.

with oak scantling ten inches square, the whole securely bolted together by one and a quarter inch rods passing through the planks. Inside of this chest was placed an iron fire box twelve feet six inches long, six feet wide, and one foot ten inches deep, with vertical flues, six of fifteen inches diameter and two of twelve inches diameter; through these the water circulated, the fire acting around them and passing up into an oval flue situated just above the fire box, carried from the back of the boiler to near the front, and returned again to the back, where it entered the chimney. This fire box and flues appear to have been at first made entirely of cast-iron; then a wrought-iron fire box was made, the flues still being of cast-iron; this not being satisfactory on account of the unequal contraction and expansion of the two metals causing leakage, eventually wrought-iron flues were also put in."

"Great advantage was at the time supposed to be gained by the non-conducting powers of the wood, and also by the vertical flues in the fire box."

"By experiments made with the engines when the above described wooden boiler was in use, it was recorded that the engine at Chestnut Street, on the Schuylkill, whilst lifting the water to the height of thirty-nine feet, and running at a speed of sixteen revolutions per minute, raised 1,474,500 ale gallons of 232 cubic inches each, in twenty-four hours, with a consumption of seventy bushels of Virginia coal. And the engine at Centre Square, raising the water fifty-one feet, pumped 962,520 ale gallons in twenty-four hours, with a consumption of fifty-five bushels of the same kind of coal; the pressure of steam, in both cases, being two and one-half pounds to the square inch." Taking the weight of a bushel of Virginia coal to be 100 lbs., these figures give the *duty* of the Chestnut Street engine as 4,790,000 lbs. of water raised one foot high per 100 lbs. (one bushel) of coal; and the duty of the Centre Square engine, 4,091,000 foot-lbs. The duty of an ordinary steam pumping engine to-day is about 30 millions, while the average duty of the best may possibly rise to 90 millions. The great gain has arisen from the use of higher pressure of steam than was practiced by Watt.

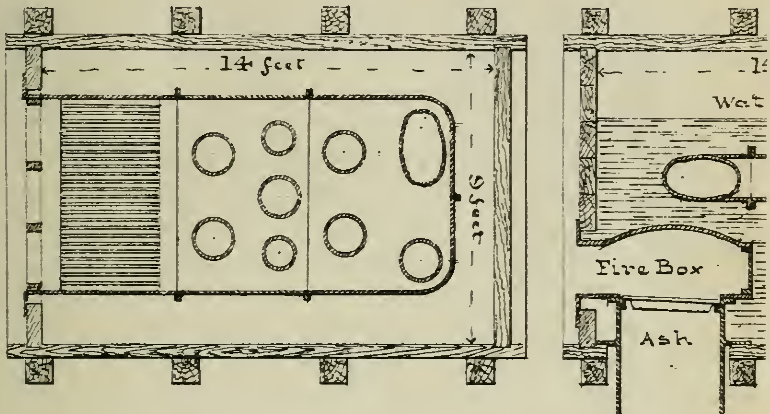
"The engine at the Schuylkill was started December 22, 1800, and that at Centre Square, January 27, 1801. The contract for them both was made March 21, 1799, the cost to be $30,000. The contractor claimed that they cost him $77,192."

Mr. Latrobe now furnishes a description of the wooden boilers:

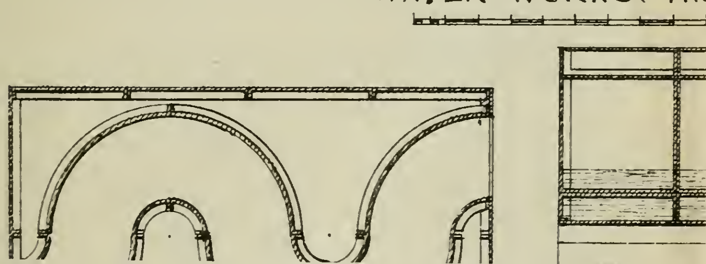
"Wooden boilers have been applied in America to the purpose of distilling for many years. Mr. Anderson, whose improvements in that art are well known, appears to have first introduced them in America. But it was found that the mash had a very injurious effect upon the solidity of the wood: for while the outside retained the appearance of soundness, and the inside that of a burnt, but hard surface, the body of the plank was entirely decayed. It was however still to be tried whether simple water and steam would have the same effect: and upon the hint of Chancellor Livingston, our present Ambassador in France, Messrs. Roosevelt, Smallman and Staudinger contrived the wooden boiler, which has been used for all the engines in New York and Philadelphia; and not without its great, though only temporary, advantages. The construction of the wooden boiler, will be best understood, by reference to the plan and section of the new boiler of the engine in Centre Square, Philadelphia, which is by far the best of those which have been made. It is in fact only a wooden chest containing the water, in which a furnace is contrived, of which the flues wind several times through the water, before they discharge themselves into the chimney."

A plan and two sections—one longitudinal and one cross section—of this boiler are given in the Plate II—the three uppermost views "from 1801 to 1815." It will be seen that it had a flat fire chamber back of the fire box, the sides of which one stayed by short tubular castings, forming water tubes, and from the back end of which an oval up-take smoke flue passed off—this oval smoke flue was carried by a bend and a return bend forward and back, below the water line. The grate was 3 ft. long $\times$ 5 ft. wide $=$ 15 square ft., while the heating surface was nearly 360 square ft. (estimating top and bottom of chamber).

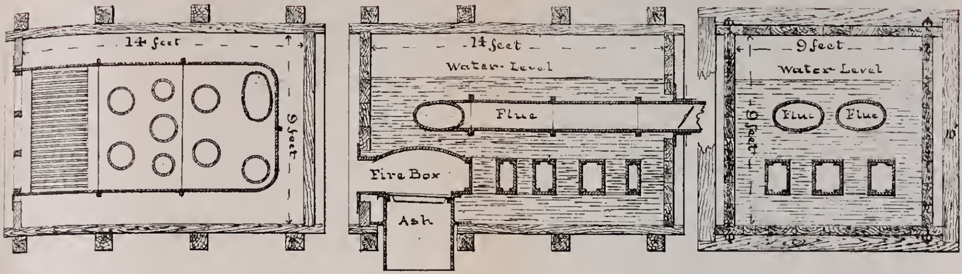
"This boiler differs from the others [*sic.* from those previously built ?] in the addition of the upright cylinders of the fire-bed, and in the elliptical form of its flues. The merits of this boiler are—that as the wood, in which the water is contained, is a very slow conductor of heat, a great saving of fuel is thereby effected; especially as an opportunity is afforded, by means of the cylindrical heaters and of the length of the flue, to expose a very large surface of iron containing water to the action of the fire. An idea of this saving may be formed, by the quantity of coal consumed by the engine in the Centre Square,



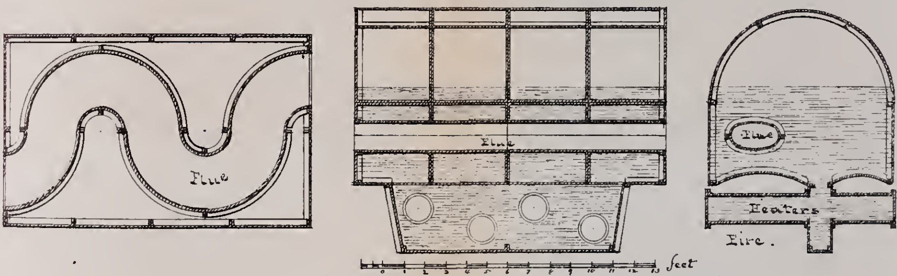
Plan and Sections of the Wooden Stea
WATER WORKS. FR



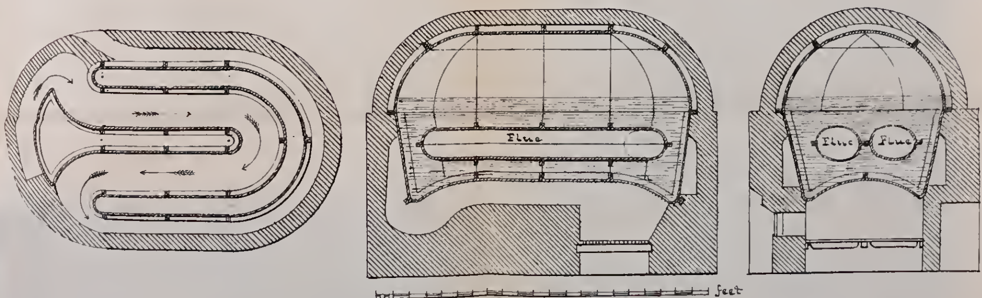
Journal of the Franklin Institute, Vol. C II.



Plan and Sections of the Wooden Steam Boiler used at the CENTRE SQUARE WATER WORKS. FROM 1801 TO 1815.



Cast Iron Boiler Centre Square Water Works 1804



Cast Iron BOILER in use at the Schuylkill Engine House Philadelphia Water Works from 1803 to 1815

Fred. Graff

which is a double steam-engine, the diameter of whose cylinder is 32 inches. The power of this engine is calculated to answer the future, as well as to supply the present wants of the city; it is therefore kept irregularly at work, filling, alternately, the elevated reservoir, and stopping during the time which is occupied by the discharge of the water into the city. It may, however, be fairly rated to go at the rate of 12 strokes, of 6 feet, per minute, for 16 hours in 24, during which time it consumes from 25 to 33 bushels of Virginia coals of the best sort. Of the amount of the saving, I cannot venture to make an estimate; on account of the great variety of coal with which we are supplied, much of which is of a very indifferent quality. That there is a great saving is certain; and while the wooden boilers continue steam-tight (for that part which contains the water gives no trouble), they are certainly equal, if not superior, to every other. The wood, however, which is above the water, and is acted upon by the steam, seems to lose its solidity in the course of time; and steam-leaks arise in the joints, and wherever a bolt passes through. The joint-leaks may for a considerable time be easily stopped, by screwing up the bolts that hold the planks together; but it is not so easy to cure the bolt-leaks; for the bolt, when screwed up, bends the top or the sides inwards, and forces new leaks, either along the corners, or at some other bolt-hole. I do not, however, believe, that everything has as yet been done, which could be done, to obviate these defects. A conical wooden boiler hooped would not be subject to some of them: such a one has been applied by Mr. Oliver Evans to his small steam-engine. During two years, which have elapsed since the boilers of the public engines have been erected, much has been done to improve them. Whether the last boiler will prove as perfect in its wood-work, as it is in its furnaces and flues, is still to be ascertained by experience. At present nothing can work better.

"I will only mention one other circumstance, the knowledge of which may prevent similar mischief.—In the first boiler erected in Philadelphia, oak timber was used to support the sides, bottom, and top of the boilers, the plank of which was white pine, 4 inches thick. In less than a year it was discovered, that the substance of the pine plank, to the depth of an inch, was entirely destroyed by the acid of the oak. Means were then used to prevent its further action, by the intervention of putty and pasteboard; and in most cases by substituting pine timbers in the room of those of oak."

As might be expected, great difficulty was experienced in keeping these boilers steam tight; accordingly, on December 1, 1801, a boiler with cast-iron shell, as well as flues, was put up, and another one, also of cast-iron, but of different form, was put in use March 10, 1803.

The first was erected at Centre Square. It had a semi-circular top, the ends being flat; the fire passed under the boiler around heaters of peculiar construction and through one flue of serpentine plan to the front of the boiler. This boiler had two sheets of wrought-iron upon the bottom, just over the fire, all the rest being cast-iron.

The second of these, which was erected at the works on the Schuylkill, is described by Mr. Latrobe in the following language:

"Within the last few months, a cast-iron boiler has been put up, at the lower engine, which hitherto exceeds the expectation I had formed of the facility with which steam is raised and supported by it. The engine is a double steam-engine, of 40 inches cylinder, and 6 feet stroke. The boiler has straight sides, and semicircular ends; it is 17 feet long, and 8 feet wide at the bottom; and nineteen feet long, and 10 feet wide at the height of 5 feet 7 inches. At this height, it is covered by a vault; which, in its transverse section, is semicircular; and in its longitudinal section exhibits half of its plan. The bottom is concave every way; rising one foot in the centre. The fire-place is 6 feet long, and at an average 4 feet wide; and is under one extreme end of the bottom. The fire-bed is arched, parallel with the bottom, leaving a space of one foot high, for the passage of the flame. At the end opposite to the fire-place, the flame descends along the bottom of the boiler, and, passing under an arch of fire-bricks, which protects the flanch of the bottom, strikes the side of the boiler at its extreme end. Here it enters a flat elliptical flue, which, passing into the boiler, follows its form, returning again and coming out near the place at which it entered. The entering part of the flue is separated from the returning flue, by a partition of fire-bricks. The flue, on coming out of the boiler, turns short round, and is carried round the whole boiler until it enters the chimney;" as will be more clearly shown by referring to Plate II, where the three lowermost views give the plan and two sections.

"The whole boiler is tied together internally by numerous braces, which are forked and bolted together upon the flanches, and are indispensable to prevent the boiler from bursting.

"The boiler is composed of 70 plates of iron, cast with flanches, and bolted together, so that the flanch and bolts are within the water of the boiler wherever the flame touches it; otherwise they would be burned off in a few days. The pieces are so contrived as to be of only 12 different patterns. This boiler consumed 50 bushels of coal, and ½ a cord of wood, while rolling iron 12 hours, at 20 strokes per minute, and pumping water 6 hours, at 12 strokes per minute.

"I will only further observe, that this boiler requires a very active fireman; and it is my opinion, that if it were 3 feet longer, a more moderate fire would raise the same steam and consume less fuel. The permanence of this boiler renders it very superior to the wooden one; and the difference of the consumption of fuel in each, in proportion to the size of the engine, is not great."

According to Mr. Graff, "The boilers heretofore described remained in use at Chestnut Street, Schuylkill, and at Centre Square, until the steam pumping works were started in Fairmount in 1815, at which time both the Chestnut Street and the Centre Square pumping stations were discontinued."

"In October, 1807, a new wooden fly wheel shaft was put into the Schuylkill engine, and also that at Centre Square; the latter engine at the same time had a new wooden lever beam made, the old ones being found rotten. This latter engine had a fly wheel of 20 feet diameter substituted for the wheel of 16 feet diameter, first used. Neither of the pumps were originally provided with air chambers; such an appliance was put to the Centre Square engine, June, 1810."

Mr. Latrobe says that the want of a valve on the main, or of an air vessel, "has these disadvantages—as long as the engine makes only 11 or 12 strokes per minute, no inconvenience whatever is perceived in working the pumps. But in the engine in Centre Square, which raises the water (in an 18 inch pipe) 51 feet, the attempt to work faster than 12 strokes per minute is in vain, . . . giving the engine shocks which seem to endanger every part of it."

Mr. Graff reports, "The expense of keeping the engines running in 1809 is reported:

	$6,254.36	for the Schuylkill engine.
and	7,552.87	for the Centre Square engine.
	$13,807.23	together.

"The engine and pump first put in at Fairmount, which was started to supply the city September 7, 1815, was almost similar to those at Schuylkill and Centre Square works, except that the lever beam and fly wheel arms and shafts were made of cast-iron. They were all on the Boulton and Watt style of that period, with poppet valves worked by hand gear and tappets.

"The dimensions of this engine were: steam cylinder 43⅝ inches diameter, and six feet stroke; lever beam, cast in two leaves, was 23 feet 9 inches long, between centres; the pump was double acting, 20 inches diameter and 6 feet stroke; the water was raised 102 feet above low tide; the boiler, as before stated, was cast-iron."

"The castings for the engine were made by Samuel Richards, at Weymouth Furnace, and at a foundry then situated within a fourth of a mile of Fairmount. The price paid was, for the cylinder castings, $160 per ton; for lever beam, $120; for fly wheel and shaft, $100; and for the cast-iron boiler plates, $90 per ton; the weight of the latter was 16 tons 12 hundredweight and 39 pounds."

"The founder reported that the castings of the cylinder (which had to be cast with the nozzles for the side pipes separate) took all the metal that the 'Eagle Works' would hold, viz., 35 hundredweight.

"This engine, with steam at 2½ pounds above the atmosphere, raised 2,116,382 United States gallons, with the consumption of seven cords of oak wood; the run was for twenty-four hours, but after the first eight hours it was found difficult to keep the steam up to 2½ pounds pressure, and the engine finally stopped for want of steam; the chimney flue was afterwards enlarged, and then steam was carried up to 4 pounds to the square inch; the engine cost $54,341."

"The boiler at Fairmount was of cast iron, and of the same plan and internal arrangement as shown in the drawings, Plate II, for the *wooden* boiler of original use at the Centre Square. Externally the shell had a semi-cylindrical top, the whole exterior being of cast-iron. This boiler continued in use from the day of commencing to pump by steam at this station (September 7, 1815, to January 14, 1822), when steam-power was discontinued and water-power was substituted."

"At this Fairmount station Oliver Evans erected the first large high pressure engine made by him."

"It had a steam cylinder 20 inches diameter and five feet stroke, with a rotating steam valve, worked by bevel gear wheels, driven

Plate III

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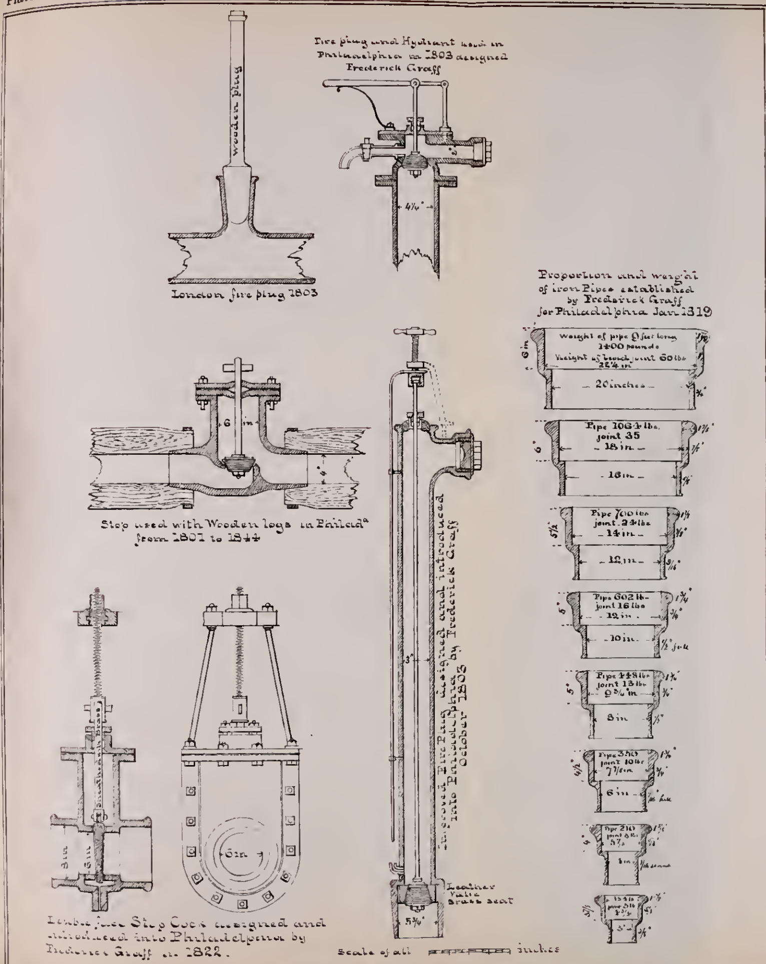
Wooden plug
London fire plug 1803
Fire plug and Hydrant used in Philadelphia in 1803 designed Frederick Graff
Proportion and weight of iron Pipes established by Frederick Graff for Philadelphia Jan. 1819
Weight of pipe 9 feet long 1400 pounds
Weight of branch joint 60 lbs.
20 inches
Pipe 1064 lbs. joint 35
18 in.
16 in.
Pipe 700 lbs. joint 24 lbs.
14 in.
12 in.
Pipe 602 lbs. joint 16 lbs.
12 in.
10 in.
Pipe 448 lbs. joint 13 lbs.
8 in.
6 in.
Stop used with Wooden logs in Philad^a from 1801 to 1844
Improved Fire Plug designed and introduced into Philadelphia by Frederick Graff October 1803
Leather Valve
Brass seat
Stuffing box with Brass
Double faced Stop Cock designed and introduced into Philadelphia by Frederick Graff in 1822.
Scale of all inches

from the main shaft; it had a double acting pump 20 inches diameter and 5 feet stroke; the beam was made of wood, and was suspended at one end upon vibrating standards, the piston rod being attached to the other end of the beam. The boilers were wrought-iron, 27 feet long, 27 inches diameter, and 4 in number, upon which steam was at times raised to 220 pounds to the square inch."

"A trial or test of this engine of Oliver Evans, for the purpose of ascertaining if it would work in conformity with requirements of contract, was made on the 15th of May, 1817. Report states that the result was not altogether satisfactory. The actual performance, however, was that it run twenty-three and a half hours; filled the reservoir 9 feet 5 inches deep, being equal to 3,666,021 United States gallons, maintained steam from 194 to 200 pounds to the square inch, and burned 13 cords of oak wood, running at a speed of 22 revolutions per minute."

"The Oliver Evans boilers, with their high pressure, certainly did not give acceptable final results. They burst twice—first, June 20, 1818, when three men were killed by the explosion; and again, Oct. 12, 1821, this time without loss of life."

"The use of both these Fairmount engines was discontinued when water power was substituted. They remained standing in the building (yet in existence at Fairmount) until May 10, 1832, when they were sold, and soon after broken up and removed."

"The distributing pipes at first used in Philadelphia, and which continued in use generally until 1819, were made of bored spruce pine logs, faucet and spiggot ends, with the faucet end wrought iron banded. Although it is probable that cast iron pipe was used to some extent before the date given, for on Plate III * is shown the standard sizes adopted at that time, as established by Frederick Graff, Sr., then Chief Engineer of the Water Works, and is also shown the old stops used with the wooden logs, which it will be seen is in general arrangement much like the 'globe valves' of the present day."

"And also the fire-plugs and stop-cocks designed by Mr. Graff in 1803 and 1822; no fire-plug or stop has been invented since (to my knowledge) that does not contain the general principle, and almost the mechanical form, of these early hydraulic appliances."

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* In the American editions of "Nicholson's Operative Mechanic," 1830–31, will be found a table of thicknesses of iron in the body and weights per yard of pipes, made after the scale shown on Plate III: the scale itself is here published for the first time.

"The first of the large water mains was cast at the charcoal blast furnaces of Mr. Samuel Richards; one of the very earliest of them is to be seen in the section of the American Society of Civil Engineers, at the Centennial Exhibition. [Attached to this pipe is the following inscription: "One of the first cast iron water mains made in America, cast by Samuel Richards, laid at Broad and Market Streets, Philadelphia, June, 1820. In constant use, 53 years; made according to the specifications and system of mains, established by Frederick Graff, Sen., January 26th, 1819. The price paid for these mains was $\$7\frac{42}{100}$ per lineal foot, about 5 cents per pound; weight, each 9 ft. given length, about 1400 pounds."] It exhibits the state of the founder's art at the time when it was cast, and also shows how durable such pipes are, when conveying the water of the Schuylkill, or resisting external corrosion from the action of the soil of Philadelphia."

GAS WORKS ENGINEERING.

By Robert Briggs, C. E.

[Continued from Vol. cii, page 199.]

"It should be stated that the figures and dimensions of parts of apparatus at the Market street works are from recollection of statements of the foreman of the works, and from memory of the observations by me, which were gathered in two visits to the works, of about one hour each, and they are not to be accepted as accurate data, but only as conveying to the mind the relative idea of magnitude, within close limits, to the facts.

"[§ § *Four.*] It next will be proper to show what is the approved and best practice in purifying gas at the present time for the purpose of comparison with that employed at the Market street works.

"As noticed in the first part of this affidavit, the earliest successful attempt to purify gas was by means of lime-water, and except for the difficulty of disposing of the foul water, it would probably have never been superseded.

"The wet-lime process consisted in passing the crude gas in small streams or broad, thin sheets through a mixture of lime and water of the consistency of the well-known white-wash.

"The spent material had (and has yet when used) all the filthiness of foul-lime as usually made, concentrated by about twice the proportion of objectionable substances, added to which is the absorbed ammonia in the watery portion, and the whole is liquid, so that it must be run off from the works.

"The labor attending the purifying of the gas, however, after the stirrers, vats, etc., are once established, is quite as little as is demanded by the later process of dry lime, and the purified gas resulting is excellent. Although the dry-lime process was introduced in England as early as 1815, it was quite thirty years before it superseded generally the wet-lime one in the United Kingdom; and, in 1850, in this country, the opinion of most the gas-works managers (then comparatively few in number) was as decidedly against the feasibility of purifying by dry lime, as a similar opinion was against oxide-of-iron processes in 1850.

"Professor Chandler says the wet-lime process is yet in use at Cork, Ireland, and it is probably also in use in a few other places in the kingdom.

"In this country, I think that it is only at Boston that it continues to be used, and the managers of the works are yet well satisfied with the resulting quality of the gas. I learn from Mr. W. W. Greenough, the agent and treasurer of the Boston Gas-Works, 'that the foul-lime water after use in the purifiers is run into a close tank, without any exposure to the air, where it is allowed to settle and the water drained off into a dock or tank, where it is again retained and still further clarified, almost all the lime remaining in the dock.' It can be averred, without much exaggeration, that the discharge of any foul water into the harbor of Boston will not materially increase its vileness.

"The invention of Hills', of oxide of iron as a purifying agent, was at once seized upon by British gas-makers; some paid the claimed royalties, others used the material and defended themselves, and many an expensive lawsuit followed. Hills had the satisfaction of winning and obtaining some remuneration, and at the expiration of his patent his method was so well established that none of the larger gas-works neglected to adopt it, and since that time no considerable works have been built in Great Britain using lime purification alone.

It always happens that during the existence (life) of any original patent no improvement is apparently made. This fact arises from the want of interest by those who use the patent, in the publication of what they individually are accomplishing, or improving upon, in their practice; and it followed in this case, as in others, that when, in 1863, Hill's patent expired, there was little record available in this country, describing the details of its use, although the process had met nearly universal adoption. I was, therefore, in 1866, glad to avail myself of the opportunity to see how far the oxide of iron process succeeded, and to examine the methods of use. Taking one of the larger works in the kingdom, under management of the highest reputation, for an example; I found at the Pagoda works of the Birmingham and Staffordshire Gas-Light Company, Mr. Hugh Young, manager, the process of purification was as follows:—First, 'a single purifier with *one* wooden screen only, on which was two inches of sawdust wet with weak sulphuric acid. After this the ammonia test was perfect; a paper each month [constantly exposed] being taken to show for that month of exposure at the meter no ammonia was present [had been passed].' 'Next followed for the removal of sulphur, a set of four purifiers, three of the number being in use for the purpose at any one time; each of these purifiers had two trays of oxide of iron, each seven inches deep, [the oxide] lasting one week without changing [any one of the purifiers being thus changed each three weeks,] and then requiring three days' exposure for revivification, the oxide of iron answering for three or four months before chemical change to sulphate [?] is effected to so great an extent as to impair its action, it is then sent to the chemical works to be used in the manufacture of sulphuric acid. In the bottom of these purifiers is placed one tray of two inches of hydrate of lime [dry lime as ordinarily used], which in the same time becomes snow-white carbonate by affinity with carbonic acid, this lime improves the gas two candles.'

"This was my first personal observation of the use of oxide of iron, and my time being limited, I visited no other works; but after my return to America in March, I made it a matter of great urgency upon managers of works in this country, to adopt the same or a similar process; both to avoid nuisance and reduce the cost of purifying—without success, however.

"In January, 1870, I again visited the same works and found some changes, which I communicated to my friends in this country, as follows:—'The purification is oxide of iron (red hematite ore from the bank crushed to powder, with one-third its bulk of sawdust); one ton of ore is used for each five millions of gas. Surface of oxide in purifiers, one-half what I use for lime purification, and the duration before revivification four to six times as long as is usual for the lime to become foul. The layers of oxide used are six inches to eight inches deep in the boxes, but the oxide must be spread about two or three inches thick on the revivifying floor. No offensive odor is exhaled at any time by the oxide of iron. Of course, the pressure on the purifiers is heavy—fourteen inches of water column in all. The seals of the boxes are two feet deep and the boxes four feet three inches deep, and three layers of oxide are used.

"'The arrangement is a pair of *ammonia* purifiers, 16′ by 16′ by 3′ or 4 feet, one of which is used alternately for removal of ammonia from the gas, giving to *two* sets, of four each, oxide purifiers, 20′ by 20′ by 4′ 3″ (of these oxide purifiers only three of each operate at once), and the gas from these two sets to one (of a pair of) carbonate purifiers 16′ by 16′ by 3′ or 4′. In the ammonia purifier, sawdust, damped with sulphuric acid, was used; one of them is emptied once in three weeks. With this precaution the ammonia test is absolutely perfect. The sawdust is supplied and removed for nothing. A lime-purifier is changed each three or four weeks, and the removal of carbonic acid was nearly perfect at all times. The lime could be reburned, but the farmers took it away at prices which paid for new-burnt lime. The sulphur-test was below inspection allowance always, and the gas was sixteen candles. There is no secret, mystery or trouble with oxide-of-iron purification.'

"These works are about half the size of the Philadelphia works. There are, or were, two companies in Birmingham; but the district of the Birmingham and Staffordshire Gas Company is down in my notes as thirty miles extreme length, and ten miles extreme width, with three principal works, and a make of one thousand millions per annum; and with over three hundred miles of connected mains.

"In the Paris Gas Works, at La Villette, the material known as 'Laming process' is in use, being a mixture of *prepared oxide*—that is, oxide of iron made from copperas (sulphate of iron), wood cut-

tings from a planing machine, and slaked lime in proper proportions. I find notes of this:— * * * 'The revivifying-room was strong with pure ammonia, but there was not the least offensive smell in all the works.' * *

"It would be possible for me to quote from my notes the process and a description, with proportions of the apparatus for purifying, at several works, in London particularly, but it would only exhibit a repetition of the same general facts, and it is sufficient to say here that all my observation, with the best-known works, failed to impress me any more favorably than those at Birmingham did. Since 1870, the progress of coal-gas making has changed very little, but numerous publications have been made, in which the actual practice of gas purification with oxide of iron and its adjuncts has been well described; accompanied, to be sure, by more brilliant notices of schemes, which make it difficult for a practical man to distinguish between real performance and projected expectation.

"The introduction of the use of oxide-of-iron purification in the works of the United States is yet very rare, but for some two or three years back the system has been employed at the 'New York' Gas Works in New York City, where a patent mixture of St. John and Cartwright is in use, and also more recently, at the Mutual Gas Works, another oxide-of-iron mixture is used, which is understood to be under another patent or to be a secret. On the 17th of February last I visited these works.

"At the 'New York' Gas Works, which are located on Avenue A and East Seventeenth street, (occupying two or three blocks or parts of blocks, on or near the East river), I found the ordinary construction of a modern, well-planned gas works. The operations of the works were transacted with usual care, order, and with much regard to avoid or prevent any nuisance. The several settings of benches I was told, aggregated eight hundred retorts, (13″ by 23″ by 9′), and two hundred and sixty pounds of coal was used with five changes in twenty-four hours. It was at these works that I first saw the mechanical charger before referred to. The emanations from coke-quenching and retort opening and charging, escaped at the ventilators, but as the works are on the level of the adjoining streets, the steam and smoke ascends and is dissipated so as to avoid cause of complaint.

(To be continued.)

Chemistry, Physics, Technology, etc.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS DURING THE LAST TEN YEARS.*

By Dr. A. W. Hofmann.

From the *Chemical News.*

[Continued from Vol. cii, page 144.]

Bettendorf † prepares pure hydrochloric acid by utilizing the fact that arsenious acid in a concentrated hydrochloric solution is thrown down by protochloride of tin as a brown precipitate composed of arsenic with 1·5 to 4 per cent. of tin. He mixes the concentrated acid with a concentrated solution of stannous chloride, filters off the precipitate, and distils, thus obtaining an acid perfectly free from arsenic.

This is confirmed by Mayrhofer,‡ but Hager|| adds that if all the arsenic is not removed by filtration, the distillate again becomes arseniferous. Dietz treats the hydrochloric acid with sulphuretted hydrogen, whilst Engel employs hyposulphite of potassium for the same purpose. Of all these processes that of P. W. Hofmann is probably the only one used on a large scale. The pure hydrochloric acid required in the sugar manufacture is chiefly prepared in certain small establishments which make their sulphuric acid from sulphur, or which have at command non-arseniferous pyrites, *e. g.*, at Saarau, in Silesia.

Chlorine and Chloride of Lime.—By far the larger portion of the hydrochloric acid evolved in Leblanc's soda process is utilized in the preparation of chlorine as an intermediate product in the manufacture of chloride of lime. As is well known, the native peroxide of manganese (pyrolusite) has long been employed for this purpose. As

* "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

† Bettendorf, *Dingl. Pol. Journ.*, cxciv., 253. *Wagner, Jahresber.*, 1869, 219.

‡ Mayrhofer, *Ann. Chem. Pharmacie*, clviii., 326.

|| Hager, *Wagner Jahresber.*, 1872, 262.

long as this mineral was to be found in sufficient quantity there was no occasion to seek out any substitute. By degrees the manganese mines became less productive, the samples in the market grew poorer in the effective ingredient, peroxide of manganese, and the prices became higher. Hence, on the one hand, experiments became necessary to re-convert the chloride of manganese—the residue from the production of chlorine—into peroxide, in order thus to reduce the outlay for manganese and to bring back a useless and troublesome residue into industrial circulation; on the other hand, attempts were made to produce chlorine without the intervention of manganese.

The first procedure for the regeneration of manganese from its residues which has met with a practical application is that of Dunlop; the chloride of manganese being decomposed by carbonate of lime, and steam at a pressure of from 2 to 4 atmospheres, and the carbonate of manganese thus formed being heated to 300° to 400° C. This procedure was carried out in the colossal establishment of Messrs. Tennant, at Glasgow, but has not been generally adopted among manufacturers of chlorine. It requires costly plant, without accomplishing the required object—a perfect regeneration of the manganic oxide. An improvement on this process, although not industrially available, was that of Clemm,* who substituted carbonate of magnesia for chalk. From the magnesium chloride formed by the decomposition of the manganese chloride he liberated hydrochloric acid by means of superheated steam, whilst the magnesia simultaneously formed was again applicable for the precipitation of fresh quantities of manganese solutions. This method, therefore, provided for the regeneration of the chlorine united with the manganese, which in Dunlop's original process was lost in the almost useless form of chloride of calcium. A method of regenerating manganese, very advantageous under certain circumstances, has been devised by P.W. Hofman, and has been successfully introduced in the works at Dieuze, and in certain German establishments. The inventor combines the regeneration of manganese in a successful manner with that of sulphur.† Hofmann precipitates the solution of manganese with the yellow polysulphides of calcium obtained by the lixiviation of vat waste after prolonged exposure to the air. The manganese sulphide

* Clemm, *Dingl. Pol. Journ.*, clxxiii., 128.

† Compare Dr. F. Tiemann's remarks on the utilization of soda residues in a subsequent part of the present report.

thus obtained, containing 57·5 per cent. of sulphur, is burnt, a part of the sulphur being recovered as sulphurous acid and conducted into the chambers. The residue is heated with nitrate of soda (1 mol. to 1 atom of manganese in the residue), and thus converted into a higher oxide of manganese, which is then transferred to the chlorine stills as a manganese of 55 per cent. Oxides of nitrogen are evolved at the same time, which, with the aid of water and air, can be condensed as nitric acid. The peroxide thus obtained consumes, indeed, 2 to 3 per cent. more hydrochloric acid than native manganese, but is much more readily soluble.

Passing over other attempts at the same object, we may mention, as a curiosity, one process which proves, at least, how intense has been the desire to regenerate manganese. Esquiron and Gouin make the ingenious proposal to revivify manganese residues for the preparation of chlorine by means of chloride of lime!

Regeneration of Manganese according to Weldon.—Recently Weldon has completely succeeded in attaining the object aimed at by so many. C. Binks and J. Macquen * had previously sought to revivify the chloride by precipitating it with the quantity of hot milk of lime needful for decomposition, passing a current of hot air through the liquid, and utilizing the precipitate thus converted into higher oxides in place of fresh manganese. But Weldon was the first who succeeded in making the process technically applicable. His most essential improvement consists in the point that he uses not a sufficient quantity of milk of lime, but an excess. Considering the importance which Weldon's process for the regeneration of manganese has already attained in the modern manufacture of chlorine, since its commercial value is fully proved by its introduction in many establishments, especially in England, it may be considered permissible to describe its principles at greater length than the procedures already mentioned. The following account is founded partly on Mr. Weldon's paper in the *Chemical News* (vol. xxii., p. 145), and partly on his letter to Dr. A. W. Hofmann, dated March 12th, 1874.

Whilst, according to Weldon, hydrated manganous oxide diffused in water can be only oxidized to manganic oxide, Mn_2O_3, by forcing oxygen through the paste, it is possible, in the presence of lime or magnesia in excess, to convert the whole of the manganese into per-

* *Technologiste*, 1862, Sept. 27. *Wagner, Jahresberichte*, 1862, 237.

oxide. The latter remains united with the lime as a compound, CaO,MnO_2, or $CaMnO_3$, calcium manganite. This may be regarded either as an analogue of the hydrated peroxide of manganese, or as manganic oxide, Mn_2O_3, in which an atom of manganese is replaced by lime. Hence it follows that 1 mol. calcium manganite requires exactly as much hydrochloric acid in the preparation of chlorine as 1 mol. of Mn_2O_3. Nevertheless it is advantageous to oxidize the manganous oxide with the aid of lime, since, in the first place, the same amount of manganese performs double the duty as if it had only been converted into manganic oxide; and, secondly, the oxidation is effected with far greater ease in presence of an excess of lime. This is probably because manganous oxide is somewhat soluble in pure water or in solution of calcium chloride, and thus retards the oxidation. At least it has been experimentally proved that salts of manganese decidedly retard the progress of oxidation. If, on the other hand, there is an excess of lime, a brown solution of calcium manganite is rapidly formed, which, as experiments prove, greatly accelerates the absorption of oxygen by the deposit of manganous oxide.

Latterly, however, it has been found possible to complete the oxidation of the manganese by an increased current of air along with an increased dose of lime. Under these circumstances we may assume the formation of an acid manganite, $CaMnO_3,H_2MnO_3$. In fact, in exceptionally successful operations, calcium manganite has been obtained in which only 1 mol. of lime was present and 2 mols. peroxide of manganese. In most cases the manganese paste has the following composition:

$$0{\cdot}80 = MnO_2.$$
$$0{\cdot}20 = MnO.$$
$$0{\cdot}28 = CaO.$$

That the lime in the paste is chemically combined, and does not exist as a mere admixture, may be inferred because the product is perfectly neutral, and because lime cannot be withdrawn from it by a solution of sugar. The manganous oxide can also be oxidized by air when the lime is replaced by baryta, strontia, or soda.

On a practical scale the process is carried out as follows:—The manganese liquor from the chlorine stills is let off into tanks provided with agitators. In these it is treated with finely-divided carbonate of lime, to neutralize the free acid and to throw down any iron which may be present as oxide. The liquid is then pumped off into settling-

vats, in which it is left to become clear. Hence the clear neutral solution is run into the oxidizer—an iron cylinder, 3·66 metres in diameter and 6·61 in height. Into this, near the bottom, opens a narrow pipe which conveys steam, and one or more wider air-pipes. After the liquid has been heated to 55°—75° by a current of steam, milk of lime, prepared from finely-sifted hydrate of lime, is run in as rapidly as possible, while air is simultaneously forced in until no manganese can be detected in the filtrate. This occurs when not only all the manganese is converted into manganous oxide, but when an excess of hydrate of lime is already present. For this purpose 1·15 to 1·45 mols. lime are required to 1 mol. manganese.

Whilst air is continually introduced so much lime is added that altogether 1·5 to 1·6 equiv. of lime may be present per 1 equiv. manganese, so that, deducting the lime necessary to form chloride of calcium, only about $\frac{1}{2}$ equiv. of line may be present to 1 equiv. of manganese in the mud produced. This is at first white, but becomes gradually black as air is constantly introduced. For the charge of a cylinder to yield 2500 lbs. manganese there are required, for perfect oxidation, about 4956 cubic metres of air and five hours time; per lb. MnO_2 1·982 cubic metres of air are therefore requisite, of whose oxygen 14·8 per cent. is actually utilized.

After completed oxidation the black manganese mud is passed into setting vats, in which it is allowed to deposit until its volume can be reduced one-half by syphoning off the supernatant solution of chloride of calcium. The mud thus concentrated contains about 141 lbs. peroxide of manganese per cubic metre, and is let off into suitable vessels for the production of chlorine.

The advantages of Weldon's process, according to the inventor, are :—The consumption of muriatic acid is smaller than when native manganese is employed, so that, at least in England, 4 tons chloride of lime can be produced, on Weldon's process, with the same quantity of acid which is required for 3 tons on the old process. In Germany and the Continent altogether, the proportion may be less favorable, since the English method of developing chlorine in large stills by the introduction of steam is less economical than the Continental procedure in which small chlorine stills are heated externally. But even on the Continent the balance of the consumption of acid is in favor of Weldon's process. The consumption of muriatic acid per ton of chloride of lime is 3301 kilos. at 21° B.

A second advantage of the process is that the residues consist of a perfectly neutral solution of chloride of calcium, whilst on the old process they consist of the more dangerous acid manganese solution and of solid residues not easy to remove from the stills.

The labor required in Weldon's process is less than the old procedure, and the men are less injured by chlorine. For, since the agents, manganese mud, milk of lime, and muriatic acid, and also the residues are all liquids, it is no longer necessary to open the stills and remove the solid residues. Hence every occasion for polluting the air of the still-house by the introduction of chlorine is obviated. The stills are charged and emptied by simply opening cocks.

(To be continued.)

PHYSICS OF THE ETHER.

By S. Tolver Preston.

[With some hesitation, and at considerable inconvenience, we have felt required to make room for the following reply by Mr. Preston to a review of his book which appeared in the June and July numbers of our Journal. In handing the work to our correspondent for notice, we had no expectation of having to publish more than some half a dozen pages; and we fear that a very small number of our readers will take much interest in a discussion so purely theoretical in character. In the interests of "fair play" we could not, however, graciously refuse Mr. Preston a hearing; although we have been compelled to abbreviate by omitting some amplifications and illustrations of his views, to be found substantially in his book.—Ed.]

Since a review of my work ("Physics of the Ether")* has appeared in your valuable Journal (in two consecutive numbers for June and July), and since the reviewer has put a construction upon certain points in the work which would convey an impression different from what I had intended, I am sure therefore you will do me the justice of allowing me to point this out, and also to notice a few of the salient objections brought forward by the reviewer—lest my silence might

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*Physics of the Ether, by S. Tolver Preston; published by Messrs. E. & F. N. Spon, Charing Cross, London; & 446 Broome street, New York.

be misinterpreted. First at page 410 of the June number of your Journal, the reviewer quotes the following passage from my work (page 33, § 48). "A molecule of matter surrounded by the ether cannot possibly be in motion without disturbing the ether, and thereby giving up a dissipating continually its motion in the surrounding ether." Then the reviewer referring to the experimental fact observed by Dr. Guthrie of the attraction of a piece of card by a vibrating tuning fork, remarks as follows.—"The tuning fork expending its motion on the resisting air in order to produce a mechanical effect on the suspended card, could not continue its vibrations a single minute, did not Mr. Guthrie stand by with his violin bow to excite the motion. But where is the 'prime motor' to fiddle the molecule into continued activity?" My answer to this is that the *sun* is the prime motor or agent concerned in maintaining the vibrations of the molecule—and this I show in the same paragraph of my book as follows: (§ 48) "It follows therefore from this that the motion of molecules which is being continually dissipated in the ether must be sustained by some external source of motion, or otherwise the motion of molecules would soon cease. This is illustrated by the known fact that the motion of molecules is sustained by the sun, it being an important fact to observe that the character of the sustaining motion is a *vibratory* or wave motion traversing the ether."

Considering that the relatively almost infinitesimally feeble vibrations of masses (such as tuning forks, etc.) have been observed to produce distinct phenomena of "attraction" and "repulsion"—may it not rather be asked how, considering the enormous vibrating energy of molecules, the teaching of such facts can be consistently ignored? Can a different kind of reasoning be applied to a molecule than to a mass, or can the scale or dimensions of the vibrating portion of matter affect the reasoning? Is it not also important to draw deductions from experimental facts, or not to neglect the teaching of nature? The reviewer says that I build entirely on the "sandy foundation" of the experiments of Dr. Guthrie. It may be reasonably asked, with what propriety a foundation of experimental fact can be termed a "sandy foundation?"

The reviewer further remarks that I recognize "no such action as a fall in nature." I can only say that this is not really the fact, as for example at page 122 of my work, I state—"There are certain known facts which would tend to the conclusion that the action of the

ether in 'gravitation' was the main physical cause concerned in the original development of the sun's heat."

Another important consideration is that in accordance with the theory of "action at a distance," all the molecular actions such as "cohesion," "chemical attraction," etc., must be assumed to exist whether the molecules of matter are in motion or not in motion (*i. e.* at the absolute zero), and so by the cooling down of the sun, the matter forming it must be assumed in accordance with this theory to be irrevocably locked together by forces which preserve their full intensity even at the absolute zero (or by the cessation of molecular motion).

Now by a reference of the molecular distant actions to the molecular vibrations, or by recognizing that molecular motion is concerned in the molecular actions, or that these actions are simply dependent on and determined by molecular motion, then it is at least so far *certain* that at the absolute zero of temperature or at the cessation of molecular motion, all molecular action would cease to exist. It certainly is not implied that this solves the problem as to the possible separation of matter at a low temperature or the possible renewal of activity; but at least it may be said that the cessation of the force which locks matter together is the main key to render an eventual separation possible—also as I have pointed out in my work, the enormous quantity of disintegrated and dispersed matter *known* to exist in the form of meteoric systems, as dust, etc., deserves at least recognition as possibly affording physical evidence of a disintegration of matter affecting itself at a low temperature, or in portions of space far removed from the sun's influence. It at least appears difficult to account for the origin of such vast quantities of disintegrated matter in space unless some such cause as the above was at work.

The reviewer (page 407) appears to find a difficulty in accounting for the conservation of vis viva at the encounter of two particles of ether—and the consequent rebound of the particles. Now I would say that there would be no authority for assuming that there was a disappearance of vis viva at the encounter of the particles unless it could be said where the vis viva went to. From the fact that vis viva is indestructible, the motion of the particles is simply changed in direction at the encounter. We may hope to have a more satisfactory insight into these facts by a more accurate knowledge regarding the ultimate constitution of matter.

The reviewer remarks (page 405) that I am puzzled by the theory of "action at a distance"—"Like others of his class he is puzzled by—and cannot 'comprehend' action at a distance; therefore he is clear that it must be a fallacy." I must demur to this, for that which cannot appeal to the intellectual powers cannot puzzle, indeed the shallow nature of the theory is an argument for its rejection. Newton, as is well known, in his celebrated letters to Bentley, declared the theory to be to him an apparent "absurdity." Indeed, any unprejudiced thinker who seeks only for truth cannot surely fail to see that the theory merely consists in the assumption of the practicability of a thing without a conception of the means, which could alone form a reasonable ground to support the assumption. It surely must also be obvious, that a theory which is in itself vague cannot possibly throw the slightest light upon anything; and, therefore, to apply this theory to physical phenomena is simply to stamp them beforehand as inexplicable. Newton, in discovering the remarkable *fact* that two masses of matter situated at a distance tended to move towards each other, and that when placed at different points of space and left free to move, the energy of the movement varied in the complex ratio of the *square* of the distance of the two masses, took care not to arrogate to himself the discovery of the *cause* of this remarkable fact.

In the July number of your JOURNAL the reviewer remarks (page 64): "This radical fallacy of the 'indestructibility of *motion*' has, unfortunately, gained a considerable acceptance, and has received the support of names much higher than that of Mr. Preston." This is, undoubtedly, true; indeed, from the very fact that the whole tendency of modern science is towards the rejection of the theory of "action at a distance," and since, by the rejection of this theory, the doctrine of the Indestructibility of Motion (or the Conservation of *vis viva*), becomes an indisputable and necessary fact; it may, therefore, be truly said that the great principle of the Indestructibility of Motion is gaining acceptance in the present day. To term the principle a "radical fallacy" can, therefore, only be a dogmatic assertion, to establish which it would be necessary to prove the theory of "action at a distance" to be *true*, which has not yet been done, and that, possibly, for good reasons.

At p. 66 of your JOURNAL, the reviewer further remarks: "Although in terms Mr. Preston accepts the modern doctrine of the

'conservation of energy,' yet, as this is expressly applied by him to the infinite store normally existing in the *ether*, and as the quantity of energy manifested by matter is declared to be variable, it is too obvious to remark that the grand theorem becomes practically valueless, and that all the attempts hitherto made to deduce the principle from the deportment of sensible matter are utterly illusory and fallacious." I am at a loss to understand how this conclusion is drawn. Firstly, is it not a generally accepted fact that the "quantity of energy manifested by matter is variable?" The sun or the whole solar system, for example, is losing energy by transference to the *ether* (*i. e.*, by radiation). The energy contained in the matter forming the sun is, therefore, variable or varying—the same holding true of other stellar suns of the universe. The "dissipation of energy" in the ether is, indeed, an accepted fact supported by Thomson and others. It is, therefore, an accepted fact that the quantity of energy in matter is variable; therefore, I am at a loss to understand the criticism on this point. Secondly, as to the remark, "all the attempts hitherto made to deduce the principle (the conservation of energy) from the deportment of sensible matter, are utterly illusory and fallacious." I cannot see how this inference is arrived at. Surely to support the principle of the Conservation of *vis viva*, or the Indestructibility of Motion, can be only to *supplement* present knowledge by the principle that in all cases where *vis viva* or motion apparently disappears, it is imparted to the surrounding medium or ether, and not lost as *vis viva;* and that in all cases where motion appears to *originate* in matter, it is, in reality, derived from the surrounding ether, the collective sum total of *vis viva* remaining at every instant *constant and invariable.*

As regards this subject (at page 65), the reviewer makes the following remarks: "When the ram of a pile driver is laboriously raised to its highest position, and there held by the grapple, what has become of the motion employed in raising it? Has the arrested lifting power been converted into heat vibrations, carefully conserved and patiently waiting to be re-converted into falling motion when the director shall release the detent? Surely such an idea can hardly be entertained for one moment, by an intelligent physicist. Supposing that for sufficient reason it is determined not to let the ram fall until the following day, where then is the motion of elevation hiding itself all this time." As to the question, "what has become

of the motion employed in raising the ram?" this is a reasonable inquiry; and as to the motion being "converted into heat vibrations," I would maintain that even this might be regarded by the intelligent physicist with more satisfaction than the evident fiction, that the motion has become "latent" (much in analogy with the old theory of "latent" heat), or stored up in a non-material or spiritualistic form in the raised ram block. However, we are not reduced to the unfounded assumption of conversion into heat vibrations, for by unfettering the reason, by rejecting the theory of "action at a distance," and taking the principle of the Indestructibility of Energy for our guide, we can deduce therefrom, with certainty, the inevitable conclusion that the motion transmitted through the ram block in the act of raising it, must have been imparted to external matter (*i. e.*, to an external medium), or, otherwise, the motion would have been annihilated.

The reviewer adds (page 69): "No physical phenomenon is better established, than that *motion* (whether of molecules or masses) is constantly originating from that which is *not* motion; *i. e.*, from static *position*, as in combustion and explosion, in the galvanic battery, in the equipoised avalanche, in the overloaded suspension bridge, in the bursting water reservoir. These simple but pregnant facts outweigh all suppositions, and for such examples of reposing power, no better name has yet been devised than 'potential energy,' or 'static force.' In diametrical opposition to the fundamental kinetic postulate of our author, we announce the inductive thesis that motion, of whatever form, is *invariably* the progeny of static force." The reviewer would, therefore, give the above as proofs that motion originates from static *position*. In the first place it is difficult to see what *position* has to do with the origination of motion; secondly, it is certain that the mere deportment of the visible masses to the eye, as in the above cases, can prove nothing whatever, though it might perhaps satisfy the superficial observer who is wont to regard visible masses as including all things essential in the universe. To arrive at the true interpretation of these facts, something more than the eye is required, or it is necessary to look deeper and use the reason.

Surely, if the action of the air on masses be imperceptible to the senses, as in the case of the movement of a card towards a vibrating fork, how much more must this be the case with the action of the impalpable ether on the masses and molecules of matter.

I cannot, lastly, but refer to the apparent inconsistency of any supporter of the theory of "action at a distance," complaining of too great boldness in speculative reasoning. Surely the wildest speculation would be tame compared with the theory of "action at a distance," which may be truly said to rest upon no rational basis whatever, and was justly condemned by Newton and Faraday. An attempt to surmount the chasm of an unknown cause by a bridge even of the most feeble mechanism, is surely far better than to assume that no bridge is required, and to do nothing.

PHYSICS OF THE ETHER.

Mr. Editor:—With your permission, I propose to comment very briefly on Mr. Preston's reply to the reviewer of his treatise,—rather because I suppose that it will be expected by the few who may take any interest in the subject, than because I feel any great occasion, or any strong impulse to rejoin.

Mr. Preston's answer to the query, where is the prime motor, to *continue* the molecular vibration required for the incessant "attraction" in matter,—that "the *sun* is the prime motor" (p. 279), is obviously a shifting instead of a meeting of the difficulty; since according to his theory the sun itself has no "prime motion," but is continuously fiddled by the *ether*.* And it was in reference to this very difficulty that on the following page (411) occasion was taken to set forth the contrasted view according to the doctrine of the conservation of force, that the continuity of thermal impulse "is maintained *only* by the fresh impacts resulting from the recoils of minute successive 'falls' of material molecules." And when the solar molecules have reached their limit of *fall*, their "working" power, or potential energy will have been entirely exhausted and dissipated. This is, of course, directly contrary to the author's teleological views.

But how can the "experimental fact" displayed by Prof. Guthrie be termed with propriety a "sandy foundation" for Mr. Preston's superstructure? (p. 279). Simply because the observed "fact" has no relation or analogy to the case in hand. Admitting the ether to

* "The ether," says Mr. P., "must be the *source* of all the motions of matter; for matter cannot evolve motion out of itself;"—and "matter cannot in any case constitute a *source* of motion."

be gaseous, we might reasonably believe that an action between two contiguous molecules, similar in character and *extent* to the action between a tuning fork and a card, should exist. But the relative distance of molecules from each other demonstrably exceeds the greatest range of "approach by vibration" that ever has been or ever can be produced by Mr. Guthrie's very interesting experiments. Denying the ether to be "gaseous," there is not even the "sandy" foundation of a crude surface analogy for Mr. P. to rest his fabric upon.

When our author declares (p. 279) that it "is not really the fact" that by his scheme "there is no such thing as a *fall* in nature; there is only *propulsion;*" his very illustration fully sustains the reviewer's statement. It is scarcely profitable to descend to a verbal dispute.

Mr. Preston very correctly says (p. 280) that on the received view "all the molecular actions such as 'cohesion,' 'chemical attraction,' etc., must be assumed to exist whether the molecules of matter are in motion or not in motion (*i. e.* at the absolute zero)." And every known fact of observation fully confirms this conclusion. But Mr. P. logically infers from his own postulates that it would be "*certain* that at the absolute zero of temperature or at the cessation of molecular motion, all molecular action would cease to exist" (p. 280). He has a vague idea that the finely divided matter found to exist in meteoric systems, has become thus segregated by reason of the suspension of cohesion in a temperature of absolute zero; and he thinks it otherwise "difficult to account for the origin of such vast quantities of disintegrated matter in space" (p. 280). Surely it is quite as comprehensible that the extremely attenuated matter of primæval nebulæ should have condensed into metallic fog, or metallic rain drops, as into the larger drops of planetoids, or the still larger drops of planets and of suns. And in the finest dust of a meteoric rain, "cohesion" is as well exhibited as in the planet Jupiter.

The fundamental difficulty pointed out (on p. 407) as lying at the very threshold of all kinetic schemes,—that *motion* alone can give no account of elasticity,—is completely evaded. Mr. P. does not seem to apprehend the elementary proposition, that in a system of colliding bodies, the *vis viva* of the system is indestructible *only* on the condition that the bodies are "elastic." He says rather indefinitely: "From the fact that *vis viva* is indestructible, the motion of the

particles is simply changed in direction of the encounter. We may hope to have a more satisfactory insight into these facts by a more accurate knowledge regarding the ultimate constitution of matter" (p. 280).

Newton's "celebrated letters to Bentley" are of course pressed into service, as usual. But the kinematists always fail to remember that a quarter of a century later than the date of the third Bentley letter, Newton himself concluded that the ether should be rejected, because "there is no evidence for its existence;" and that with a more matured realization of the utter insufficiency of all speculations as to the *mode* of gravitative action, he ultimately fell back on the suggestion, "Have not the small particles of bodies certain powers, virtues, or forces, by which they *act at a distance?*" *

Mr. Preston constantly speaks of *action at a distance* as a "theory," as an assumption "without any conception of the means" (p. 281), thereby assuming that others must necessarily have the same *cacoethes fingendi* that he himself exhibits. The astronomer accepts the fact as ultimate, and therefore necessarily as "inexplicable," without presuming to theorize upon it. As Mr. P. has himself well remarked, "Newton, in discovering the remarkable *fact*, ... took care not to arrogate to himself the discovery of the *cause* of this remarkable fact" (p. 281).

To designate the "indestructibility of motion" a "radical fallacy," is only a "dogmatic assertion," says Mr. P. (p. 281). There are propositions in physics so fully established, that they may well be dogmatically asserted; and one of these is that motion (whether molecular or molar) is a phenomenon constantly exhibited to us as increasing or as diminishing, as originating *de novo* or as being destroyed. So far is the fallacy of the indestructibility of motion from "gaining acceptance at the present day," it is not believed to be admitted by a single physicist of any eminence. All motion expended in shaping matter must have forever disappeared, else would we have useful work accomplished without the sacrifice of energy. Every elliptical orbit, whether of satellite, of planet, or of comet, presents an endless recurrence of a large amount of motion quite destroyed at the *apo-apsis*, and of a corresponding increase of motion at the *peri-apsis*.

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* In the appendix to the second edition to Newton's Optics, published in 1717, Query 31.

It was urged (p. 66) that the experimental determination of the conservation of energy must be "utterly illusory and fallacious," if the energy were only transiently exhibited by matter, and were ordinarily hiding itself in the ether. Mr. P. is "at a loss to understand how this conclusion is drawn" (p. 282); and he expatiates on the "dissipation of energy." All which being neglected, it may be replied, that the energy developed in one portion of matter being observed to be abstracted from another portion, the quantitative results obtained (the waste or dissipation being reduced to a minimum) may be accepted as a close approximation to the law. But if, as alleged, the ether, instead of being the mere *vehicle* of molecular energy, is its fountain and receptacle, it is perfectly obvious that the experimentalist has no means of measuring or of following the vagaries of force.

Rejecting "the unfounded assumption of conversion into heat vibrations" of the stopped lifting motion of the pile-driving ram, Mr. P. says that "by unfettering the reason," we may reach "the inevitable conclusion" that the motion must have been imparted to an external medium, or otherwise the motion would have been annihilated" (p. 283). It is scarcely doubtful that the experienced physicist will unhesitatingly accept the latter alternative. The previous suggestion of a "latent" motion is too good to be surrendered by the ingenious kinetists, as it might serve to bridge a good many troublesome difficulties.

"It is difficult," says Mr. P., "to see what *position* has to do with the origination of motion" (p. 283). Position, though not an originator of motion, is a condition which may indisputably give to an originator of motion a great mechanical advantage. In a warfare of stones between two savages, one at the top and the other at the bottom of a precipice, the former has gravity as an ally, and the latter as an antagonist; and the first may roll down upon his enemy, masses which the latter could not even lift. And this difference in relative efficiency or energy is purely one of "position."

In regard to the illustrations of potential energy or static force given (on page 69), Mr. P. remarks "the mere deportment of visible masses to the eye, as in the above cases, can prove nothing whatever, though it might perhaps satisfy the superficial observer" (p. 283). Visibility or imperceptibility has nothing whatever to do with the question. The examples adduced were selected because the nature

and conditions of the actions were tolerably well understood. The theorist who would resolve them into cases of kinematics, has a very different task before him from the utterance of generalities as to the possible existence of impalpable agencies or invisible motions.

In his concluding paragraph Mr. Preston indulges in the illusion of a false issue, quite ignoring the opening sentence of the review (p. 405). The real objection and complaint made against all ethereal kinetists, is not to the "boldness,"—but to the incongruity, the inadequacy, the *irrationality* of their speculations. Engineers of dreamland—they would "bridge the unknown" by flights of fancy, innocently heedless of the need of any abutment upon which to rest their insubstantial arches.

William B. Taylor.

PURE YEAST: A PRELIMINARY COMMUNICATION.*

By Moritz Traube.

The author has succeeded in obtaining pure alcohol yeast, free from all other ferments and bacteria, by a simple method, which he promises to describe hereafter.

When this yeast is introduced into a decoction of yeast previously freed from organic germs by boiling, there appears at the bottom of the vessel, after some days, a tolerably abundant precipitate of perfectly pure yeast. Since an aqueous decoction of yeast does not contain grape sugar, it is thus shown that the increase of yeast is not due to fermentation nor in any way dependent on the presence of sugar. The experiment does not succeed with ordinary yeast containing bacteria. When such yeast is introduced into a decoction of yeast, the bacteria introduced with it alone increase, entirely preventing the development of yeast cells, and inducing in the liquid a putrefaction characterized by dense turbidity. Hence it is possible to determine, almost more certainly than by means of the microscope, whether yeast is absolutely free from bacteria, by introducing it into a decoction of yeast free from sugar.—*Journal of the Chemical Society.*

* *Deut. Chem. Ges. Ber.*, ix, 183.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

Vol. CII. NOVEMBER, 1876. No. 5.

EDITORIAL.

Notice.—The publication of the Journal is made under the direction of the Editor and the Committee of Publication, who endeavor to exercise such supervision of its articles, as will prevent the inculcation of errors or the advocacy of special interests, and will produce an instructive and entertaining periodical; but it must be recognized that the Franklin Institute is not responsible, as a body, for the statements and opinions advanced in its pages.

Franklin Institute.

Hall of the Institute, Oct. 18, 1876.

The stated meeting was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers, in the chair.

There were present 97 members and 11 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at its last meeting 6 persons were elected members of the Institute, and the following donations made to the Library:

Rose, H. Traité pratique d'analyse chimique. Paris, 1832. 2 Vols.

Mineralogie appliquée aux sciences chimiques. Girardin et Lecoq. Paris, 1826, 2 Vols.

Manual du mineralogiste. Paris, 1792. 2 Vols.
Essay par la voie seche. M. P. Berthier. Paris, 1834. 2 Vols.
Brard's mineralogie appliquée aux arts. Paris, 1821. 3 Vols.
Bache's System of Chemistry. Philad'a, 1819. 1 Vol.
Bullock's Fresenius Chemical Analysis. N. Y., 1844. 1 Vol.
Elemens de documastique. Paris, 1755. 4 Vols.
Sobrero & Barreswie. Appendice d'analyse Chimique. Paris, 1845. 1 Vol.
Lewis' Course of practical Chemistry. London, 1746. 1 Vol.
Ure's Dictionary of Chemistry. Philad'a, 1821. 2 Vols.
Bronginart's traité elementaire de mineralogie. Paris, 1807. 2 Vols.
Burat's Geologie appliquée. Paris. 1 Vol.
Daudenart's l'art de la vitrification. Paris, 1825. 1 Vol.
Accum's Practical essay on Analysis of Minerals. 1 Vol.
Chevreul's Recherches chimiques sur les corps gras. Paris, 1823. 1 Vol.
Manuel des pharmaciens et des droguistes (2 Vols. in 1). 1 Vol.
Cuvier. Le Regne animal &c. Paris, 1817. 4 Vols.
Rose, H. Handbuch der analytischen Chemie. Berlin, 1838. 2 Vols.
De Romé de l'isle. Cristallographie. Paris, 1783. 3 Vols.
Berzelius, J. J. Nouveau système de Mineralogie. 1 Vol.
Sage, M. Analyse chimique et concordance des 3 règnes. Paris, 1876. 3 Vols.
Beudant. Traité elementaire de Mineralogie. Paris, 1824. 1 Vol.
Liebig's Agricultural Chemistry, by Webster. Cambridge, 1842. 1 Vol.
Davis' Manual of Magnetism. Boston, 1848. 1 Vol.
Klaproth's Beiträge zur chemischen Kentniss der Mineralkörper. Berlin, 1795. 5 Vols.
Seel's Analysis of mineral waters, &c. 1838. 1 Vol.
Faraday's Manipulation Chimiques. Paris, 1827. 2 Vols.
Orfila, P. Traité des Poisons. Paris, 1818. 2 Vols.
Gay-Lussac. Cours de Chimie. Paris, 1828. 2 Vols.
Karten's Manuel de la Metallurgie du fer. Metz, 1830. 3 Vols.
Parnell's Elements of chemical analysis. London, 1842. 1 Vol.
Bergman's Manuel du mineralogiste. Paris, 1792. 1 Vol.
Berzelius, J. J. Essai sur la theorie des proportions chimiques, &c. Paris, 1819. 1 Vol.
Beudant's Traité elementaire de mineralogie. Paris, 1824. 1 Vol.
Dictionnaire technologique, &c., des arts et metiers. Paris, 1822. 24 Vols.

From Henry Seybert, Philadelphia.

Notes on Building constructions. Part 2. 1875. Encyclopædia of Chemistry. Parts 11–15. From J. B. Lippincott & Co.

Proceedings of the Davenport Academy of Natural Sciences. Vol. 1. 1867–1876. Iowa, 1876. From the Academy.

Report of the Meteorological Committee of the Royal Society for the year 1875. From the Society.

Minutes of proceedings of the Institution of Civil engineers. Vol. 45. Session 1875–76. Part 3. London, 1876. From the Institution.

Report on Machinery and Manufactures, with an account of European manufacturing districts, by Robt. H. Thurston. Wash., 1876. From the Author.

Third, Fourth and Eleventh annual reports of the geological survey of Indiana, made during the years 1871, 1872 and 1875, by E. T. Cox, State Geologist. Indianapolis, 1872 and 1876. With maps. From the Author.

Specifications and Drawings of patents issued from the U. S. Patent Office for April, 1876. Washington. From the U. S. Patent Office.

Plate glass, its manufacture in the United States, by W. F. Durfee and A. Gobert. Philada., 1876. From the Authors.

An account of the American Antiquarian Society, located at Worcester, Mass. From the Society.

Public Libraries in the United States of America, their history, condition and management. Special report. Dept. of Interior, Bureau of Education. Wash., 1876. From the Am. Library Association.

The Actuary also reported the following from the proceedings of the Board at its last meeting:

Mr. Wm. P. Tatham, chairman of the Committee on Exhibition, reported that in accordance with the action of the Board in May last, requesting the committee to correspond with other societies of like character in the Atlantic cities, with the view to quadrinal exhibitions in Boston, New York, Philadelphia and Baltimore, a correspondence was opened with the societies named, resulting in a conference of committees from the Massachusetts Charitable Mechanics' Association, of Boston, and the Maryland Institute, of Baltimore, with the Committee on Exhibitions of the Franklin Institute, at which conference the following Report was adopted:

"The Convention of the representatives of the following societies, to wit:

"The Massachusetts Charitable Mechanics' Association,

"The Franklin Institute,

"The Maryland Institute,

assembled at the room of the Franklin Institute, Machinery Hall, Centennial Exhibition, at the invitation of the Franklin Institute, upon the 23d of September, 1876, agree upon this report to their several constituent societies:

" *Whereas*, The Centennial Exhibition now in progress has presented to the people a model on such a grand scale that it must necessarily exalt the standard of such exhibitions, and enlarge public expectation with regard to them, and

" *Whereas*, Such expectations can best be satisfied by the united efforts of the societies named it is recommended:

(1) "That they abandon the system of annual or independent exhibitions heretofore pursued, which have to a certain extent interfered with each other, and agree to hold only one exhibition in each year by turns in the several cities of the seaboard.

(2) "To such exhibitions the members of all the societies shall have free admission under proper safeguards.

(3) "The exhibition in each city shall be at the expense and for the profit of the local society holding it and subject to all the rules and regulations imposed by the said society except as provided in the preceding paragraphs.

(4) "That, to secure some uniformity however, in the character and proceedings of the exhibitions, and with a view of affording an index of progress from year to year, the societies be recommended to unite in a classification of exhibits and a uniform system of appointing Judges. The classification of the goods to be based upon the position of each article in trade and not upon its use, so as to enable us to secure competent and expert judges of a whole class. The judges to be appointed one by each society for each class. The recommendations in this paragraph to be adopted or not by each society, at its option.

"Should variety be insisted upon, the principle of reciprocity to be adopted.

"(Signed) {
JOSEPH L. BATES, *for Mass. Ch. Mech. Ass'n.*
W. P. TATHAM, *for Franklin Institute.*
JNO. M. CARTER, *on behalf of Md. Institute.*"

The Actuary further reported the following action of the Board:

"*Resolved*, that the following petition, duly signed by the President and Actuary, be presented to the City Councils:

"To the Select and Common Councils of the City of Philadelphia,

"The petition of the Board of Managers of the Franklin Institute, of the State of Pennsylvania, for the promotion of the Mechanic Arts, respectfully showeth,

"That the Franklin Institute is a corporation which for more than fifty years has labored with success for the object of its creation, by helping men to help themselves; by bringing together the men of science and the men of practice, to the instruction of both; by establishing a library, schools and lectures; by rewarding men of skill and ingenuity, and by exhibitions of their various productions.

"This last named purpose requires a hall far beyond the means of the Institute to command; and this is especially the case, since the Grand Model of the Centennial Exhibition has been seen by the people.

"Your petitioners, therefore, pray that Machinery Hall may be maintained and preserved for the purpose mentioned, as well as for such other public purposes as the proper authorities may direct."

And also, on motion of Mr. Fraley,

"*Resolved*, that notices of meetings be sent to all those members who are not more than one year in arrears for dues."

The President, having occasion to withdraw, here called Vice-President J. E. Mitchell to the chair, and he presided during the remainder of the meeting.

The Chairman introduced Capt. L. P. Sementschkin and Prof. Ashleyman, of the Royal Polytechnical Schools of Moscow and St. Petersburg; and the former gave explanations of the system of technical education in Russia.

The Secretary presented his report, which embraced illustrated descriptions of F. G. Fowler's Feathering propeller for steam vessels; Boynton and Adamson's Torpedo Boat; P. H. Dudley's Dynograph for determining Railway resistances; E. Dornheim's adjustable automatic fan for bedsteads; the ultimatum lamp burner for burning petroleum oils; and of a ball supported by a jet of steam at an angle of 40° from the perpendicular.

The Secretary called attention to the establishment by the Society of Arts of London, of a prize medal in Industrial Hygiene.

The Secretary made the following announcements:

The class in phonetic short hand having proved so successful (numbering now nearly seventy pupils), it has been decided to open

a day class for the accommodation of those who are unable to attend in the evening. The session of this class will be on Friday of each week, at 4 P.M., commencing on the 27th inst.

The time of opening the lecture season has been deferred until after the close of the Centennial Exhibition, and has been fixed for Tuesday, Nov. 14th.

The subject of the adoption of the Majority Report on the Metric System of Weights and Measures was called up, when, on motion, its further consideration was postponed to the next stated meeting.

On motion, the meeting adjourned.

J. B. KNIGHT, *Secretary.*

Continuation of List of Donations from the Meeting of the Institute held September 20th, 1876.

Fifty-sixth Annual Report of the Managers of the Apprentices Library Co. Phila, 1876. From the Company.

Ninth Annual Report of the Provost to Trustees of Peabody Institute. June 1, 1876. From the Trustees.

Laws governing the Steamboat Inspection Service. Washington, 1875. General Rules and Regulations prescribed by the Board of Supervising Inspectors of Steam Vessels and approved by the Secretary of the Treasury, 1875. Washington, 1875. From the Board.

Die Schmalspurige Montan—Bahn von Rostoken nach Marksdorf in Ungarn von Paul Klunzinger. Wien, 1875. Schnee Schutzvorkehrungen auf Amerikanischen und eurapaischen eisenbahnen. By E. Pontzen. Wein, 1874. Schlussbericht über den vorzunehmenden Ausban der Wasserstrassen in Frankreich, &c., &c. Wein, 1875. Uber hölzerne Brücken unter besonderm henweisse auf Amerikanische Gerust-brücken (Trestle Bridges), von E. Pontzen, Wien. Offentliche Bauten auf der Welt Ausstellung zu Paris im Jahre 1867. Besprochen von Ernest Pontzen. Wien, 1868. From the Author.

Specifications and Drawings of Patents, U. S. Patent Office, January, February and March, 1876. From the Commissioner.

Le Canal Maritime de Suez Illustré. Histoire du canal et des travaux par M. M. Fontane, Paris, 1869. Compagnie Universelle du Canal Maritime de Suez. 12em—19em Reunion, 1870—1875. Rapport de M. F. De Lesseps, &c., &c. From Prof. J. E. Nourse. Washington.

Elements of Physical Manipulation, by Edward C. Pickering. Part II. New York, 1876. From Hurd and Houghton, publishers.

Practical Treatise on the Construction of Iron Highway Bridges, for the use of town committees, &c. By A. P. Boller. 1876. From Claxton, Remsen & Haffelfinger, Philadelphia.

Notice du Plan en Relief du Canal Maritime de Suez. Exposé dans la salle de Lesseps Musée de Marine au Louvre. Paris, 1875.

The Maritime Canal of Suez. Brief memoir of the enterprise from its earliest date, &c., by Prof. J. E. Nourse. Washington, 1870. From the Author.

General Index of Official Gazette and Monthly Volumes of Patents of the U. S. P. O. for 1875. From the Patent Office.

Geological Survey of Canada. Report of progress for 1874–75. From the Director of the Survey.

Memoirs of the Geological Survey of India. Vol. XI, Part 2. Memoirs of the Geological Survey of India; Palæontology Indica; Jurassic Fauna of Kutch. Vol. 1—4. Ser. IX—4. The Cephalopoda. By Wm. Waagen, Ph. D. Calcutta, 1875. From the Office of the Survey.

Twenty-third Annual Report of the Managers of the State Lunatic Asylum, Utica, N. Y., for 1875. From the Managers.

American Iron Trade in 1876. Politically, &c., considered. By James M. Swank. From the A. I. & S. Asso., Phila.

Contribution to the Meteorology of Japan. By Thos. H. Jizard. From the Meteorological Committee, London.

On the Tides of the Arctic Seas. By the Rev. Saml. Houghton, M.D. From the Royal Society, London.

Monthly Report of the Department of Agriculture for July, 1876. Washington, 1876. From the Department.

Report of the Superintendent of the U. S. Coast Survey for 1873. From J. E. Hilgard, Assistant in Charge of U. S. C. S. Office.

Pennsylvania Archives, Sec. Ser., Vol. 4. Harrisburg, 1876. From J. B. Lynn.

An Address on some of the Leading Public Health Questions, by J. M. Toner, M.D. From the Author.

Etudes Electrochimiques des dérivés du Benzol, par Frederic Goppelsroeder. Mulhouse, 1876. From the Author.

Reports of the Commissioners of the U. S. to the International Exhibition, held at Vienna, 1873. 4 Vols. Washington, 1876. From the Secretary of State.

Educational institutions, Province of Ontario, Canada. Toronto, 1876. Home and foreign trade of Canada. By W. J. Patterson. Dominion of Canada. Catalogue of exhibits in Education Department. Toronto, 1876. From John Laidlow.

New South Wales, its progress and resources. Sydney, 1876. Mineral map and general statistics of New South Wales. Sydney, 1876. Official Catalogue of the natural and industrial products of New South Wales. Mines and mineral statistics of New South Wales, &c. Industrial progress of New South Wales, being a report of the

International Exhibition of 1870 at Sydney, &c. From the Commissioners of New South Wales, through their Secretary, Charles Robinson.

Memoria presentada al empresario constructor, Dr. D. Dioniso Derteano por V. A. Lastarria. Lima, 1876. El Departamento de ancachs y sus Riquezas minerals. Por A. Raimonti. Lima, 1873. From W. W. Evans, C.E., New York.

Woods and minerals of New Brunswick, &c., by Baily & Jack. From the authors.

Twentieth annual report of the Board of Trustees of water works, to City Council of Cleveland, &c., for 1875. From John Whitelaw, Supt. and Eng.

Annual report of the U. S. Geological and Geographical survey of the territories embracing Colorado, for 1873. By F. V. Hayden, Washington. From Secretary of Interior.

Annual report of the Secretary of Internal Affairs of Pennsylvania, for 1874–75. Pt. 3, Industrial statistics, Vol. 3. Harrisburg, 1876.

Tabulated results, compiled from the annual reports of Railroads, Passenger, &c., Co's of Pennsylvania, for the year ending December 31, 1875. From the Secretary of Internal Affairs.

British patent reports, issued between May 13th and July 29th, 1876. Abridgments of specifications relating to the manufacture of paper, pasteboard and papier mâché. Pt. II, A. D. 1858–1866. Second edition. London, 1876. Ditto Grinding grain and dressing flour and meal. A.D. 1623–1866. London, 1876. Ditto Purifying and filtering water, including the distillation of sea water to produce fresh water. A. D. 1675–1866. London, 1876. From the British Patent Office.

American Ephemeris and Nautical Almanac for the year 1876. Washington, 1876. From Prof. J. H. C. Coffin.

Report of the Meteorological office of the Dominion of Canada, for the year ended 31st December, 1875. From G. T. Kingston, Superintendent.

Annual Report of the Light House Board, to the Secretary of the Treasury, for the year 1875. Washington. Annual Report of the Supervising Architect, to the Secretary of the Treasury, for the year 1875. Washington. Catalogue of recently added books, Library of Congress, 1873–75, with index to subjects and titles. Washington, 1876. Maps of the U. S., showing extent of public surveys, &c., compiled from the official surveys of General Land Office, &c., under the direction of Hon. S. S. Burdett, Commissioner, 1874 & 75. From Hon. Chas. O'Neill, Philada.

Reports of the Commissioners of the United States to the International Exhibition, held at Vienna, 1873. 4 Vols. Washington, 1876. By R. H. Thurston. From the Author.

Five complete volumes and 20 numbers of the Journal Franklin Institute. From the Historical Society of Pennsylvania.

Announcement of Lectures to be given before the Franklin Institute at the Hall, commencing November 14th, 1876.

Six Lectures by Prof. Edwin J. Houston, on Light.
November 14th, 21st, 28th, Dec. 5th, 12th, 19th.

Eight Lectures by Prof. Wm. D. Marks, on Dynamics.
November 16th, 23d, December 7th, 14th, 21st, January 4th, 11th, 18th.

One Lecture by Mr. Henry Whitall, on Astronomy.
January 2d.

Five Lectures by Prof. Elihu Thomson, on Electricity.
January 9th, 16th, 23d, 30th, February 6th.

Eight Lectures by Dr. Horace Binney Hare, on Chemistry.
January 25th, February 1st, 8th, 15th, 22d, March 1st, 8th, 15th.

One Lecture by Mr. Robert Briggs, on Prevention of Railroad Accidents.
February 13th.

Two Lectures by Mr. Alex. E. Outerbridge, Jr., on Metallurgy and Assaying of Precious Metals.
February 20th, 27th.

Three Lectures by Prof. Pliny E. Chase, on Inventions, Ornamental Iron Work and Ceramics.
March 6th, 13th, 20th

The Lectures on Dynamics, by Prof. Marks, and on Chemistry, by Dr. Hare, form an elementary series upon the respective subjects.

The Warming and Ventilation of Churches.*—This is, in one respect, undoubtedly the most trying season of the year —not for weakly people alone, but for ordinary and even robust mortals, who are not proof against "catching cold" and the divers afflictions which in natural sequence frequently follow—in so far as by present structural arrangements it is impossible to regulate the temperature of churches, &c., where large numbers of people are assembled; and chiefly and naturally this difficulty is increased in the now chilly evenings. While the internal atmosphere is rising in temperature, the *ex*ternal is falling; hence the inflow of the cooling and denser air into the midst of the heating and rarifying atmosphere of necessity causes a strong and dangerous current of cold air to descend, in some particular parts of the building, on heated, and so, susceptible persons. Is it *quite* beyond the grasp of our architects to master this difficulty? In one of the churches of Torquay, being placed for some time near the cold limestone wall at the west end,

* From *The Builder*, London, Sept. 23, 1876.

which reaches up to the lofty roof, the downpour of cool air was so great that I moved my place, while others left the church, the strength of the current increasing as the service proceeded, and the atmosphere of the crowded church becoming continually more heated, forced the air into more rapid motion, naturally driving the expanded and lightened—because heated—air up to the roof, where, finding no escape, and becoming cooled by contact with the cool roof, it necessarily descended by the cold walls—the circulation thus set up being precisely that which takes place in boiling water in a vessel where the heat is applied beneath the centre only, as when a spirit-lamp is used, the water as it becomes heated ascending in the centre of the vessel and descending against the cooler sides. Is it impossible to contrive means to arrest these air currents? In a second church in the town, columns of cold air are let down from the clear-story windows on the devoted head of some unfortunate who is seated immediately beneath them, and to my cost I have found that through a heated, and therefore rarified, air, a column of cold, and therefore condensed, air will fall, with considerable force and weight. Last evening I had the misfortune to be placed within the arc which was formed by the horizontal projection of a stream of cold and heavy air from the window of a side aisle, on its passage to the floor.

These churches are the work of some of our leading architects, and yet, by these defects, are rendered not only unsuited to the purpose for which they were erected, but absolutely unsafe. And I cannot but think that a little study of the laws which govern these currents of air would lead to a remedy. Surely the present state of our churches and places of public assembly in this respect is a blot on the practice of scientific architecture.

Ancient Toughened Glass.—In a "Book of Curiosities" we read: "There was an artificer in Rome who made vessels of glass of so tenacious a temper that they were as little liable to be broken as those that are made of gold and silver. When, therefore, he had made a vial of the purer sort, and such as he thought a present worthy of Cæsar alone, he was admitted into the presence of their then Emperor Tiberius. The gift was praised, the skilful hand of the artist applauded, and the donation of the giver accepted. The artist, that he might enhance the wonder of the spectators, and promote himself yet further in the favor of the emperor, desired the vial out of

Cæsar's hand, and threw it with such force against the floor, that the most solid metal would have received some damage or bruise thereby. Cæsar was not only amazed, but affrighted with the act; but the artist taking up the vial from the ground (which was not broken, but only bruised together, as if the substance of the glass had put on the temperature of brass), drew out an instrument from his bosom and beat it out to its former figure. This done he imagined that he had conquered the world, as believing that he had merited an acqaintance with Cæsar and raised the admiration of all the beholders; but it fell out otherwise, for the emperor inquired if any other person besides himself was privy to the like tempering of glass. When he had told him 'No,' he commanded his attendants to strike off his head, saying, 'That should this artifice come once to be known, gold and silver would be of as little value as the dirt in the street.' Long after this—viz., in 1610—we read that, among other rare presents then sent from the Sophy of Persia to the King of Spain, were six mirrors of malleable glass so exquisitely tempered that they could not be broken."—*London Times.*

ENGINEERING ON THE SOUTHERN PACIFIC RAILROAD.

[From the *Mining and Scientific Press*, San Francisco, Cal., Sept. 9th, 1876.]

The event of driving the last spike in the railroad connection between San Francisco and Los Angelos, which occurred on Tuesday last, was one of great importance, indicating as it does the gradual opening up of southern California, Arizona, etc., and bringing them into more direct communication. The road passes through the San Joaquin valley, from Lathrop in the north (where the line branches from the Central Pacific), to Tehichipa, a distance of 300 miles, on almost a level. The work of track-laying was comparatively inexpensive, with bridges crossing the Stanislaus, Tuolumne, Merced, Fresno, and Kern rivers, and other streams flowing from the mountains to the San Joaquin. The San Joaquin Valley railroad, which comprises this section of the road, intersects the counties of Stanislaus, San Joaquin, Merced, Fresno, Kern and Tulare, and all the products of Tuolomne and Mariposa counties will find their way to market on this great highway.

The only natural passes across the barrier separating Los Angelos from San Francisco are the Tehichipa and Tejon passes, the former of which was chosen by the railroad engineers as the easier through which to run their track, and from there it debouches into the Mohave desert. These were not the only obstructions to be overcome, and the San Fernando tunnel, the longest on this side of the continent, had to be bored, and the work was performed with more than ordinary expedition.

San Francisco is now placed in communication by rail with Los Angelos, San Bernardino, Santa Monica, Wilmington, Anaheim and Santa Ana. Los Angelos is now the centre of an extensive railroad system, branches extending to Santa Monica, Wilmington and Anaheim, besides the main trunk of the Southern Pacific railroad, which runs through it. The branches extending to Wilmington and Anaheim are owned and controlled by the Southern Pacific railroad company; that to Santa Monica is the nucleus of the Los Angelos and Independence railroad. All that remains of the Southern Pacific railroad to be built is from Indian Wells to the Colorado river, at or near Fort Yuma.

The engineering difficulties in building this road were very great, and those encountered in ascending the Tehichipa canyon surpass anything encountered on an equal distance in the Sierra Nevada. Every artifice had to be employed to enable the engine to climb the steep grade, and within 19 miles there are 17 tunnels in ascending the Tehichipa. A few statistics regarding the length and size of these tunnels cannot prove uninteresting. Tunnel No. 1 is 245·8 feet long; No. 2, 232·2 feet; No. 3, 707·7 feet; No. 4, 257 feet; No. 5, 1,156·3 feet; No. 6, 303·7 feet; No. 7, 532·7 feet; No. 8, 690 feet; No. 9, 426·2 feet; No. 10, 406·6 feet; No. 11, 158·8 feet; No. 12, 756·3 feet; No. 13, 513·8 feet; No. 14, 512·7 feet; No. 15, 360·7 feet; No. 16, 262·5 feet; No. 17, 260·9 feet; making a total of 7,683·9 feet. Nearly all these tunnels are heavily timbered with staunch 11x14 inch red-wood timbers. At the bottom they are 14 feet in the clear, or 16½ feet in excavation. They are 22 feet in height, and the shoulders at the springing of the arch are 18 feet 4 inches. In the Soledad canyon there are two more tunnels, numbered 18 and 19, the first being 264 feet long, and the latter 332 feet. The longest tunnel on the coast is the San Fernando tunnel, 6,966½ feet in length.

This tunnel was commenced on March 27th, 1875, the headings met July 14th, 1876, and the timbering was completed August 9th, 1876. It is built on a slope of 37 feet to the mile, and is perfectly straight, so that one can see through it. It is not cut through a single mountain, as is the case with most undertakings of this kind, but runs through a succession of ridges and canyons. The entire length is 6,966 feet, or nearly a mile and a quarter. This is exclusive of the heavily graded approaches, which aggregate half or three-quarters of a mile more. The deepest point in the tunnel is 600 feet below the top of the mountain. The excavation is made in the form of a trapezoid, only that the top, which forms the longest side of the figure, is surmounted by an arch. The width of the bottom is 14 feet, the height of sides to the commencement of each, 16 feet, and the height to centre of arch 21 feet. The sides and top are protected by heavy timbers, braced, fitted and spiked into the aperture as soon as the earth is removed. The south approach ascends at a grade of two feet in 100, until it reaches the mouth of the tunnel, where the road bed strikes a uniform gradient of 71-100ths of a foot in 100, rising toward the north. At the northern extremity it reaches its highest point, and then descends with the same incline as the southern approach. Work was commenced simultaneously at both ends, and at three intermediate points on the line of the tunnel. From these points inclines were sunk to the level of the road-bed to further the work of excavation and provide ventilating facilities when the tunnel was completed. The tunneling was originally started some distance from the present face, but the overlying earth caved in so badly that it was found necessary to make excavations about sixty feet deep before sufficiently solid earth was found. Another obstacle which presented itself, was an excessive flow of water, rendering the work of excavating not only dangerous but very expensive.

Tunnel 9 is at the famous loop of Tehichipa pass. This loop completely encircles a mound, and by so doing gains a difference in elevation of 77 feet 6 inches. Emerging from tunnel 9, the train winds around the mound and passes directly over the tunnel at right angles, having made a curvature of 300° 52′. The length of the loop is 3,794 feet. Pictured on the map this loop looks like a coil thrown carelessly in a rope; it is a veritable corkscrew. It is claimed to be a novel and original achievement in engineering. The total

length of tunnels between Caliente and Los Angelos, as given above, is 15,246.4 feet.

The road has been built to within 100 miles of the Colorado river, which it will reach before the close of the year. The whole distance from here to Fort Yuma by the road is 715 miles, over 600 of which are completed.

HEAT-CONDUCTION IN GASES.

[From *English Mechanic and World of Science.*]

The power of different gases to conduct heat has in recent years been frequently studied, both in the way of theoretical calculation and of experimental measurement. The researches of M. Stefan have an important bearing on the theory of gases. Recently M. Winkelmann has published a new investigation of the subject in *Poggendorff's Annalen.*

For measurement of the heat-conduction, M. Winkelmann employed the same method as has been employed by other observers: he measured the velocity of cooling of a thermometric body within a vessel filled with the gas to be examined. The difficulty of these experiments lies in the circumstance that the cooling is caused not only by the conduction of the gas which surrounds the cooling body, but that also the currents of the gas, and above all, radiation, play an important part. M. Winkelmann considered it his chief task to eliminate the currents of the radiation; and he effected this in one case by altering the pressure of the gas between 760 and 1mm. (with decreasing pressure the action of gas currents becomes less). Secondly, he employed various apparatuses in which the cooling body within was always of the same dimensions and the same material, while the outer envelope was altered in size; the value of the radiation was then in all apparatuses the same, while the conduction varied with the size of the outer vessel, and so furnished data by means of which the radiation could be calculated and eliminated.

The results of these measurements are given in the following table:—

Gases.	Conductivity.
Air, ...	0·0000525
Hydrogen, ...	0·0003325
Carbonic acid, ...	0·0000317
Ethylene, ...	414
Marsh gas, ...	647
Nitric oxyde, ...	460
Carbonic oxide, ...	510
Oxygen, ...	563
Protoxide of nitrogen, . . .	363
Nitrogen, ...	524

The numbers obtained for air and hydrogen, the gases with which the fullest series of experiments were made, further showed that in air, down to a pressure of 1mm., the heat-conduction is *independent* of the pressure; hydrogen, on the contrary, showed a quite divergent and hitherto unexplained behavior in reference to pressure, in that the changes of the currents with different pressures by no means afford an explanation of the observed differences in velocity of cooling.

For example, whereas with a lowering of the pressure from 750mm. to 91·4mm., there was a change of only 1·4 per cent. in the value for the velocity of cooling; on further diminution of the pressure to 4·7mm., there was a further decrease of 11 per cent., and this decrease continued when the pressure was further lowered to 1·92mm. Whether, perhaps, accidental circumstances may have operated here, or whether the phenomenon is due to properties of the gas, can only be decided by further and more exact researches.

A second task which M. Winkelmann set himself was to determine the relation of heat-conduction to temperature. In this investigation he had to employ new apparatus made of glass, and to effect the separation of the conduction from the radiation on a different principle from that in the first measurements. The observations were so arranged that first the time of cooling was determined from 18° to 8°, and then from 118° to 108°. With three apparatuses very different in their dimensions, M. Winkelmann obtained the temperature co-efficients 1·3661, 1·3429, and 1·3644, referring to the temperatures 7°·4 to 7°·6, and 107°·7 to 109°; that is to say, if the heat-conduction at the lower temperature be put equal to 1, then at the higher temperature it has the value just given.

Besides the two gases, air and hydrogen, carbonic acid was examined. If the latter changes its heat-conduction with temperature

in the same way as air and hydrogen, we should, by combination of the values of hydrogen and carbonic acid, obtain the same relative numbers as those given relating to hydrogen and air. The values so obtained, however, are altogether smaller, whence it appears that the conduction of carbonic acid is not dependent on temperature in quite the same way as that of hydrogen, but increases more quickly with the temperature.

Book Notices.

CHEMIA COARTATA, OR THE KEY TO MODERN CHEMISTRY, by A. H. Kollmyer, A. M., M. D., Prof. University of Bishop's College, etc. 1 Vol. 8vo, oblong. 107 pp. Lindsay & Blakistone, Phila., 1876.

The purpose of this book is to supply a reference text book of chemistry, and this end is reached in an exceedingly convenient and comprehensive way. The extended double page gives width of sheet, so that six or seven columns can be made to show at one view: 1st, the name of the element, followed by derived substances; 2d, some historic data; 3d, the sources from which obtained; 4th, the chemical equations of the sources and process of derivation; 5th, the chemical and physical qualities—the properties; 6th, the tests of most ready application or use. The author claims that "It will be found especially adapted to the wants of: 1st, students intending to present themselves for examination; 2d, persons who have learned the old notation and wish to become acquainted with the *modern system;* 3d, those who desire to keep up their useful knowledge of chemistry while actively engaged in other pursuits;" and this claim seems fully warranted. It is literally a handbook of chemistry, filling a want not supplied by other books, and not appreciated by other writers, and it will unquestionably meet with an extended sale and immediate use.

"DE LA TRANSMISSION ET DE LA DISTRIBUTION DES FORCES MOTRICES A GRANDE DISTANCE PAR A. ACHARD" C.E. Geneva, etc., extracted from the "Annales des mines" with additions. 1 Vol. 8vo. 156 pp., Dunod. Paris, 1876.

Attention is called to this work, so that any whose professional acquirements lead them to investigate the transmission of motive power by wire ropes, by compressed air or liquid pressure, will know where to look for a very complete study and exhibition both of principles and actual usage. The work is well worthy to be studied by every mechanical engineer, and its publication in separate form renders it available for the shelves of a library.

Civil and Mechanical Engineering.

HYDRAULIC RIVETING MACHINES.

By Wm. Sellers & Co.

In the earliest form of riveting machine, the riveting die was actuated either by a crank or a cam, so that the traverse of the die was uniform, and determined by this driving mechanism. The rivet, whether large or small, long or short, was compressed to the same length, often in rivet holes of varying diameters. Sometimes, therefore, the rivet did not fill the hole; sometimes the plates to be riveted were strained. The work was performed by gradual compression, in itself desirable, but the uniform traverse, operating upon irregular quantities in the rivet, and even forcing the metal into holes of varying capacity, failed to produce regular work.

The direct action steam riveting machine produces regular work with irregular quantities in the rivet or varying size of holes; but inasmuch as the work is done by a blow, the shock is, in time, destructive to the machine, and sometimes is injurious to the work.

Hydraulic riveting was first accomplished by a machine on which hydraulic pressure was employed to act directly upon a compressing piston, which carried the riveting die; but in all these hydraulic machines, a pump was employed to produce the pressure in the compressing cylinder, which cylinder was in communication with the pump chamber through a valve which was opened by the fluid whenever the pressure in the pump chamber exceeded that in the cylinder; consequently the compressing piston, which carried the die, was moved only when the pump moved to force the fluid through the valve, and rested when the pump was taking water for its next stroke. Hence the die might be stationary, while a rivet was but partially headed. Moreover, the compressing piston and die did not move at the will of the operator, but with the motion of the pump, whether it was worked by hand or power. If by hand, the workman had no means of controlling the pressure but by his judgment or strength;

if by power, a valve to release the pressure was provided, which could be opened by the operator whenever, in his judgment, a sufficient pressure had been exerted, but no means of determining this with any degree of accuracy was provided in either case, so that, although the pressure was gradual, and the traverse limited only by the performance of the work, the want of means to determine the latter produced irregular results.

Mr. Ralph H. Tweddell, of Sunderland, Great Britain, is the inventor of a hydraulic riveting machine in which is combined all of the advantages and which avoids all the difficulties which have characterized previous machine systems—that is to say, his machine compresses without a blow, and with a uniform pressure at will; each rivet is driven with a single progressive movement, controlled at will. The pressure upon the rivet after it is driven is maintained, or the die is retracted at will. And to this combination he adds features not heretofore found in any riveting machine.

This machine consists of a riveting die and a holder, one or the other attached to and moved by a piston in a cylinder, which is called the compressing cylinder; this cylinder communicating with an accumulator through a valve, not self-acting, but moved by the operator, so that when the valve is opened the piston to which the die or the die holder is attached invariably moves until the rivet is headed, with a force which is positively defined by the pressure on the accumulator. Hence the work is performed without a blow; the pressure is uniform whether the rivets are long or short; it can be modified by the weights applied to the accumulator; it is continuous for each rivet, and may be maintained as long as desired, or the riveting die can be retracted as soon as the rivet is finished, whether the pump is taking water, delivering it, or at rest.

The accumulator above alluded to is an essential part of the system; it is of variable capacity; in it water is kept under pressure, being forced in by means of a pump, or otherwise. The chamber of the accumulator is closed at one end, and to the other end is fitted a stuffing box, through which plays a weighted piston-rod or plunger. This plunger rises or falls as the quantity of water in the chamber increases or diminishes. By varying the load upon the plunger the pressure upon the water in the accumulator cylinder is adjusted. The water or other fluid under pressure on the accumulator, and there

stored up ready for use, is conveyed through suitable pipes and admitted by the operating valve to the compressing cylinder of the riveting machine, so that when the valve is opened the water flows into the compressing cylinder, closing the riveting dies upon the rivet, and finishing the work with just such force or pressure as the accumulator has been gauged to produce.

The plant required for hydraulic riveting consist, therefore, of an accumulator that can be loaded so as to give any requisite pressure per square inch; a means of keeping this accumulator full by pump or otherwise; and the riveting machine proper, which may be either stationary or movable within certain limits. For boiler work a stationary riveting machine, somewhat similar in construction to our steam riveters, has its large steam cylinder replaced by a very small hydraulic cylinder. The hydraulic cylinder closes the dies quickly, but without any blow.

For bridge work construction in the shop—the pump and accumulator are placed in any convenient position, and the water under pressure is carried through jointed or flexible pipes to a portable riveting machine suspended from an over-head carriage. In using this portable riveting machine the work resting on trussels remains stationary, the riveter is moved along it from rivet to rivet to be driven, performing the work with surprising rapidity and accuracy, and without noise or jar. The whole machine or combination is also arranged for use in the field, by providing a car with boiler, engine, pumps, and accumulator on it, the portable riveter being suspended from a crane or derrick attached to the car. This permits the use of the machine in driving the rivets in bridge erection or in ship-building.

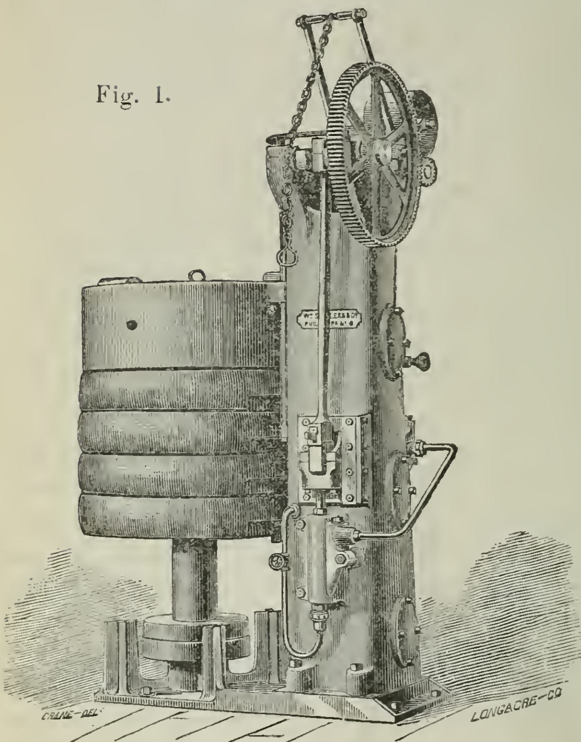
We have secured the control of this valuable invention, and are prepared to furnish the Tweddell hydraulic riveting machinery for any kind of rivet driving.

We have added to the original invention many improvements of our own, pertaining directly to it, and have arranged convenient over-head carriage and hoisting machinery to facilitate the use of the portable hydraulic riveting machine.

The following cuts and description will make the arrangement of hydraulic riveting machines more comprehensible to the reader:

ADJUSTABLE ACCUMULATOR AND PUMP.

Fig. 1.



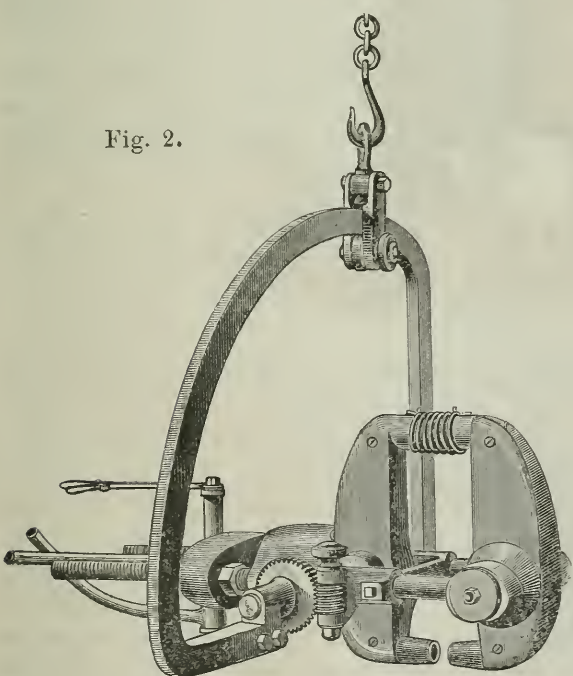
Arranged with weights suspended below the main casting, so made as to be readily released from it, to adjust the pressure to the work being done, each weight represents 250 pounds pressure per square inch on the ram of riveting machine. The maximum pressure obtainable when all weights are in place is 2000 pounds per square inch.

The pump, which is double-acting, operated by crank motion, is of improved construction, and takes its water from a reservoir in the upright. The return water in entering the reservoir passes through a mass of sponge to filter it. An important feature in the arrangement of pump and accumulator is the adaptation of our improved relief valve to the system. This valve is so constructed and controlled by the motion of the accumulator as to relieve the pump from work without stopping its motion when the accumulator is full, and to start it to pumping into the accumulator as soon as the accumulator weight has descended a short distance. When this valve is open, the water under pressure in the accumulator is shut off from the pump, and the pump relieved from pressure draws water from the reservoir and forces it back into the same reservoir, maintaining its action without

strain, but ready to resume its work when required. When the relief valve is closed, the pump forces water directly into the accumulator. When the accumulator is full, and no water is being taken from it, the pump must either stop or discharge its water elsewhere. To stop the motion of the pump when the accumulator is full, involves its being again started promptly when required, which is not very readily done, and risks the loss of water and entrance of air into the chamber while standing. To maintain the action of the pump and discharge under a safety valve involves the expenditure of power when no useful work is being done. Our arrangement maintains the motion of the pump ready for immediate action, and yet relieves it from strain when not required to do any work.

THE PORTABLE RIVETING MACHINE.

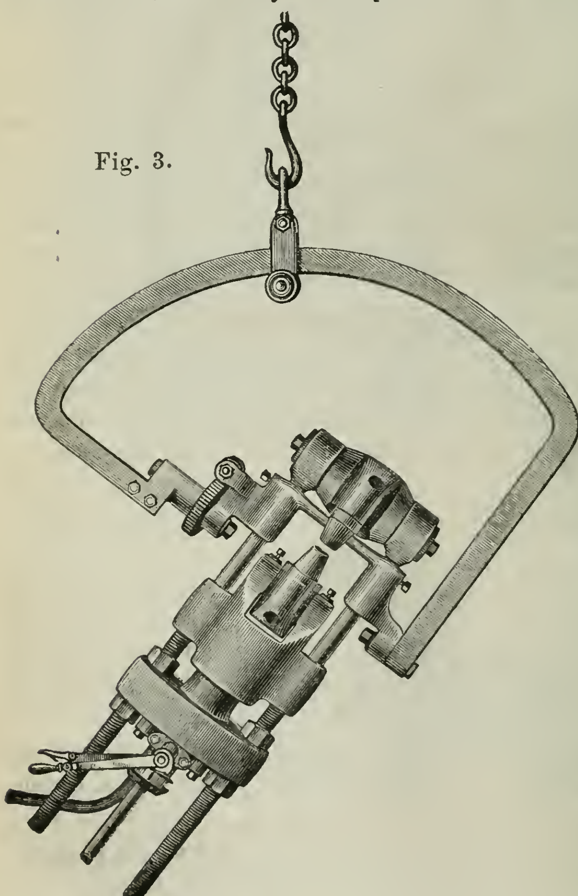
Fig. 2.



We give in Figs. 2, 3, and 4, this useful machine in three positions; showing how it may be adjusted to act readily on seams oblique, horizontal, or vertical. Fig. 2 shows the shape of the riveting jaws or levers. The rivet is driven by the dies in short ends of levers. We make these levers or jaws of various lengths, suited to different work. In all cases the proportion of the two ends is as two is to one. Thus, we make lever 6 inches and 12 inches long, 9 inches and 18 inches, or 12 inches and 24 inches. These proportions allow

plates to be riveted, where the rivets are five inches, eight inches or eleven inches from the edges of the sheets or the flange edges of angle, tee, or channel bars or beams. It is of course desirable, to avoid weight of the whole apparatus, to use the shortest and lightest levers adapted to the work in hand. For riveting boiler plates, the stationary machine with its long and massive stake, as before mentioned, is required. With the dimensions of levers which we have given, there is no trouble in obtaining strength, without passing the limit of portability for the machine, so that the pressure on the rivet shall cause the heated and plastic metal to flow into all irregularities of the rivet holes, while only the surplus of iron shall go into the heads.

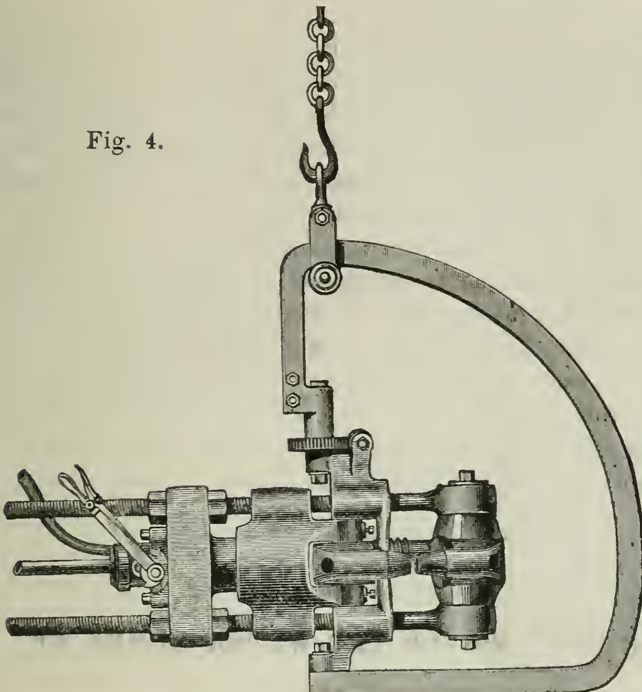
Fig. 3.



The portable riveter is suspended from a hoisting machine on an over-head carriage. This carriage having a longitudinal motion on over-head rails, of in some cases, 50 feet, and a transverse motion of 6 feet; thus permitting the use of the machine at any point within a space of 50 feet by 6 feet wide.

In this space the work rests on trussels, and the riveting machine is moved along or around it.

Fig. 4.



One man raises and lowers the riveter, adjusts it to the rivets, and then closes the dies on the rivets. Boys drop the red-hot rivets into place with the head of the rivet uppermost in horizontal work. With a skilful operator, as many as 6 to 10 red-hot rivets may be put in place ahead of him, and he can, on beam work, drive from 10 to 16 rivets per minute.

The portable hydraulic riveter is suspended from an over-head carriage; the hoisting machinery of this carriage is one of the improved forms of Weston's hoists, working with very little friction, and capable of nice adjustment of the riveting machine to any position.

The same carriage with slight alteration can be made to lift 1000 pounds, and, mounted on the same ways as carry the riveter carriage, can be used to lift and adjust the work to be riveted. To obtain the best result with these riveters, the extra hoisting machines are desirable.

In using the hydraulic riveting machine to advantage the rivets should be heated rapidly and uniformly. To accomplish this we have arranged furnaces inclosed in sheet iron covers, with every convenience for rapid handling of the rivets by the boys who attend to this part of the work.

The hydraulic riveting machinery is inexpensive to maintain, if a very little attention is paid to keeping it in good order. It, like all other hydraulic machinery, should be kept up; not allowed to deteriorate by careless usage. Slight leaks, if stopped by attention to the packing at once, will give no trouble; if neglected, may amount to serious wear from rust and abrasion.

As the portable riveting machine is most commonly applied to especial use, both in place and in description of work, it is better that a full consideration of the requirements be presented to Messrs. Wm. Sellers & Co.; but the form of machine shown in these pages is suited for many uses without change or further adaptation; while the great superiority of machine over hand riveting requires every large boiler or plate iron working shop to possess in readiness to use all the appliances needed to avoid hand work.

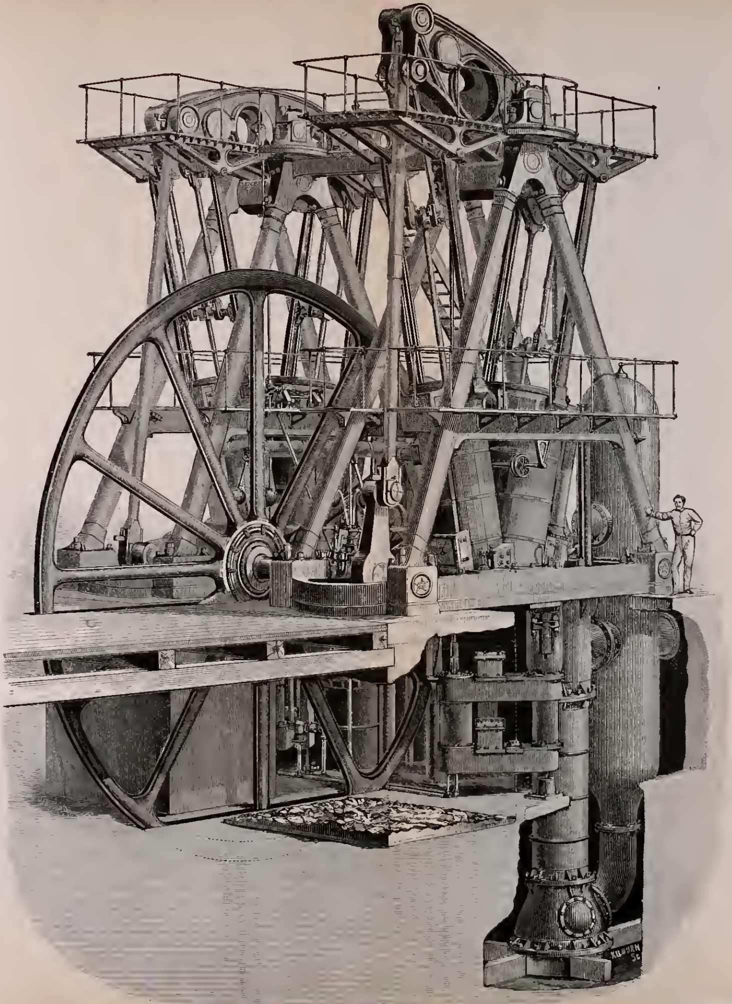
TRIAL OF THE

PUMPING ENGINES FOR THE WATER WORKS AT LAWRENCE, MASS.

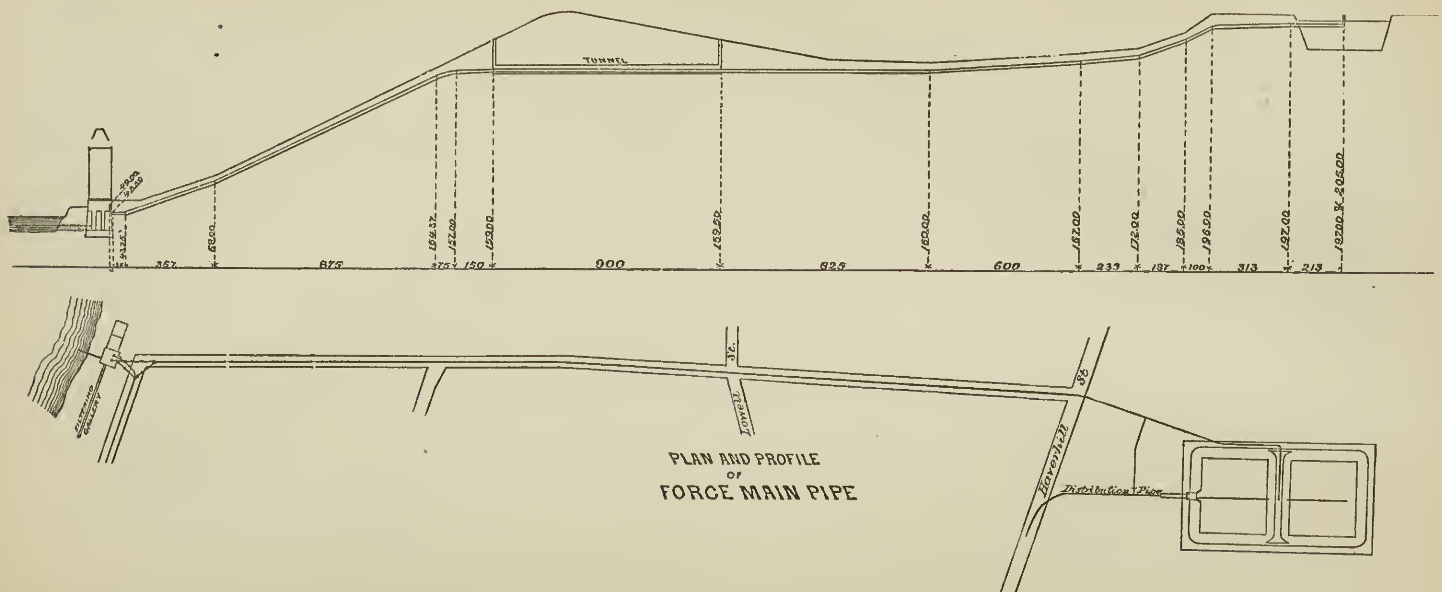
Designed and arranged by Mr. E. D. Leavitt, Jr., C.E.
Constructed by Messrs. I. P. Morris & Co., Philadelphia.

In accordance with the terms of contract between the Commissioners of the Lawrence Water Works and the builders of the boilers and engines, these engines have been subjected to a test trial under the supervision and direction of Messrs. Wm. E. Worthen, J. C. Hoadley and Jos. P. Davis, civil engineers, who were the chosen experts; and from the report made by them the following abstract has been prepared:

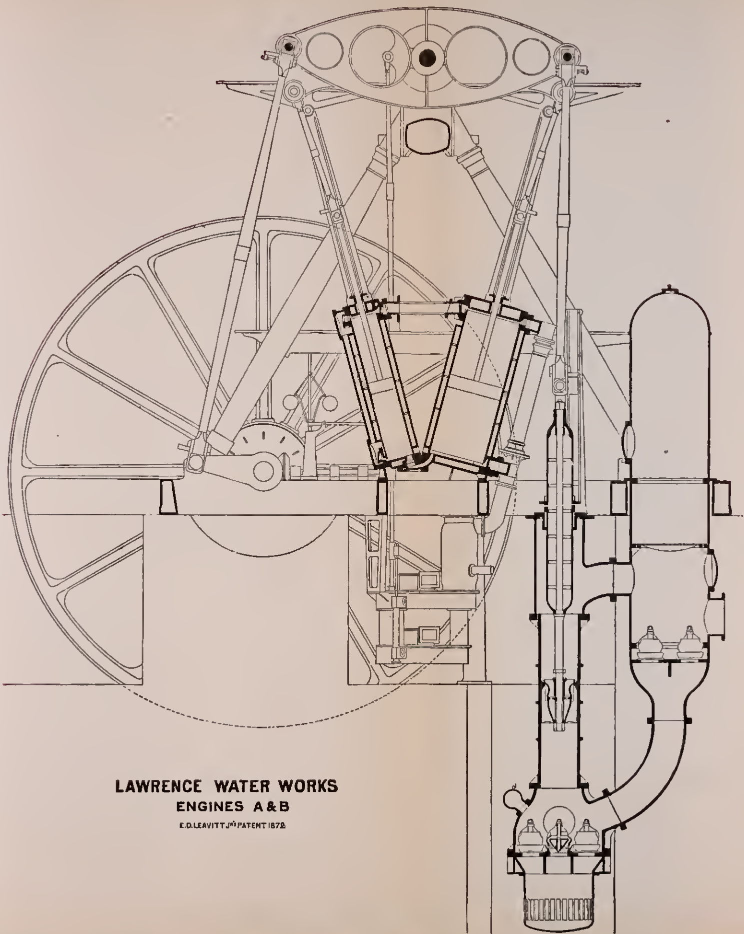
Description of Works.—Plate I contains plan and profile of engine-house, main and reservoir, by which their relative positions can be readily understood. The pumps of both engines deliver into branch mains of 24 inches diameter, and 75 feet long, thence by main 30 inches diameter and 4,900 feet long to reservoir. The delivery is usually by an overflow from the upright pipe on the centre of the division-wall of the reservoir; but, for the purpose of measurement



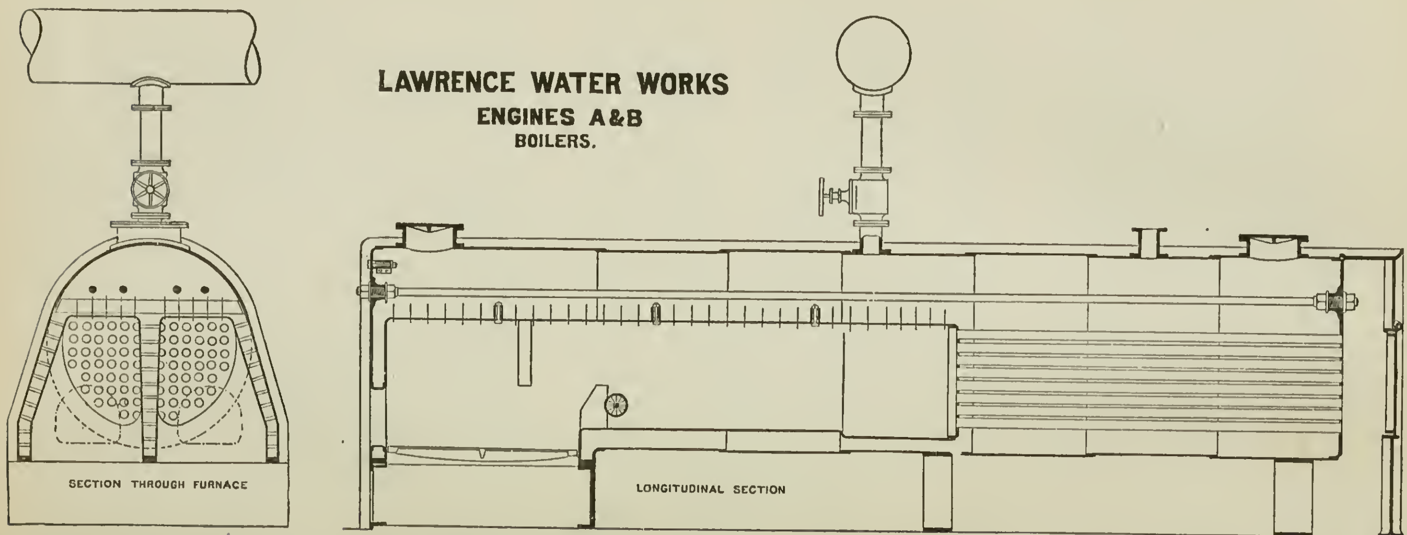
Journal of the Franklin Institute, Vol. CII.



PLAN AND PROFILE
OF
FORCE MAIN PIPE



LAWRENCE WATER WORKS
ENGINES A & B
E. D. LEAVITT Jr. PATENT 1872


LAWRENCE WATER WORKS
ENGINES A&B
BOILERS.
SECTION THROUGH FURNACE
LONGITUDINAL SECTION

by weir, this pipe was enclosed by a box, some 10 feet long by 8 feet wide and 4 feet deep. A weir was constructed on the southerly side, of which the crest was 2 feet 4 inches above the bottom of the platform—or some 4 inches above the top of the pipe. The weir measured 3·997 feet in length, plate iron edge and sides.

Engines.—The engines were two, designated as A and B, with a single fly-wheel between them. For the test of a single engine, the westerly one, or engine B, was run. Plate II is a section of one of the engines—a compound engine of Mr. E. D. Leavitt, Jr.'s, design and patent. The two steam cylinders, both steam jacketed, are placed beneath the main centre of a working beam, and inclined outwardly at the top to connect with opposite ends of the beam, reducing thereby the length of the steam passage between the cylinders, equalizing the stroke, and economizing space, with a strong and compact frame.

The cylinder valves are all gridiron valves with large area of opening and small movement. The steam valves to the high-pressure cylinders are operated by cams controlled by governors, one to each engine. When running coupled, the cam of one engine is set and the other controlled by its governor.

Air-pump double-acting. Feed pump connected with air-pump rod. The pumps are of the Thames Ditton variety, bucket and plunger, but with a supplementary delivery pipe. There are seven double-beat valves for suction, and four in the supplementary pipe, and the bucket valve for the delivery. Attached to the lower valve chamber, there is a small spherical chamber with an air-cock at the top, by which air may be introduced into the pump, which is found, at particular stages of water in the well, to contribute to ease in the working of the pump.

The boilers are two in number, designed for these works, tubular, with interior fire-boxes; the general construction will be understood from the sections, Plate III. A water mid-feather divides each boiler into two furnaces. This feather extends from the front nearly to the centre of the boiler, where both fire-boxes unite in one combustion chamber. From this chamber the boiler is tubular to the end; the products of combustion passing through the tubes, return beneath nearly to the ash-pit, and pass downward, and latterly into a depressed flue leading to the chimney.

Table of Dimensions.

Diameter of high-pressure cylinders, . . .	18	inches.
" low " " . .	38	"
" high " " rods, . .	$3\frac{1}{2}$	"
" low " " . .	4	"
" air-pumps, ...	15	"
" pump-barrel, . . .	$26\frac{1}{8}$	"
" " plunger, ...	$18\frac{1}{2}$	"
" " " rod, . . .	$4\frac{1}{2}$	"
" bottom and supplementary valves outside lower seat, . . .	$15\frac{3}{4}$	"
" bottom and supplementary valves inside upper seat, . . .	$12\frac{1}{2}$	"
" bucket-valves outside lower seat, .	22	"
" " inside " " .	15	"
" air-chamber, ...	54	"
" fly-wheel, ...	30	feet.
Length of stroke of steam and water pistons, . .	8	"
" " air-pump, . . .	28	inches.
Distances between End Centres of Beam, .	$16\frac{1}{2}$	feet.
Lead on steam-valves, ...	0	
" high-pressure exhaust valves, . .	$\frac{1}{16}$	inch.
" low " inlet, . . .	$\frac{1}{16}$	"
" " " exhaust bottom, . .	$3\frac{5}{16}$	"
" " " " top, . .	$4\frac{9}{16}$	"
All measured on stroke of pistons.		
Cushion on high-pressure top exhaust, . .	$14\frac{1}{4}$	"
" " bottom " . .	$14\frac{3}{4}$	"
" low-pressure top " . .	$4\frac{1}{2}$	"
" " bottom " . .	$8\frac{1}{4}$	"

Volume of Clearance and Port Space:

High-pressure top, . .	·0256	of cylinder capacity.
" " bottom, . .	·0231	" "
Low " top . .	·0154	" "
" " bottom, . .	·0182	" "
Connecting pipe between cylinder .	·0992 H. P."	"
Weight of fly-wheel, ...	35,900 lbs.	

Volume of Clearance and Port Space:

Weight of walking-beam including pins and counter-balance,	25,700 lbs.
" high-pressure piston and connections, .	2,575 "
" low " " " " .	4,175 "
" air-pump " " " .	1,800 "
" pump, plunger bucket, . .	7,200 "
" main connections, beam to crank, . .	3,800 "

BOILERS:

Length of shell, ...	25 ft. 5½ in.
" water mid-feather, . . .	12 feet.
" combustion chamber, . . .	3 "
" tubes, ...	10 "
Diameter of tubes, ...	3 inches.
Number "	80 "
Diameter of circular shell, . . .	5 ft. 3 in.
Length of each grate, ...	5 feet.
Width " "	2 ft. 10 in.

Steam drum for both boilers, 12 feet 6×2 feet.

FORCE MAIN:

Length of force main, ...	4,900 feet.
Diameter " "	30 inches.

Branches from engines to main, 75 feet long×24 inches diameter.
Static lift from 165 feet to 174 feet.

That part of the contract which governed the Board of Experts in conducting the test trial is as follows:

"For the test the engines shall run for forty-eight consecutive hours, during which the water will be measured over a weir at the reservoir, and the delivery of the pumps must be at the rate of at least 2,000,000 of gallons in ten hours for each engine, with a speed of sixteen revolutions per minute, and a steam pressure in boiler of 90 pounds per square inch. If, however, the Water Commissioners shall so determine, the test shall last for a less time than forty-eight hours.

"The test shall be made under the direction of at least three mechanical engineers of good reputation, one to be chosen by the Commissioners, one by the said party of the second part, and the third by the other two.

"The coal to be used on the trial shall be of the best quality of Cumberland coal, and shall be carefully weighed, and with such precautions as the examiners may determine upon.

"The method of conducting the trials to be as follows: Steam to be raised in the boilers to the proper working pressure with clean fires of the usual thickness, when the engines are to be started, and the trial is to begin; but the beginning and ending of that portion of the trial on which all calculations of efficiency and duty are based shall be left to the decision of the experts.

"All the coal burned during the trial to be charged without deduction of any kind to the engines.

"The lift to be determined by a correct pressure-gauge attached to the rising main at a point within one hundred feet of the engine house, to the average readings of which shall be added the pressure due to the difference of the level of this point, and the mean surface of the water in the pump-well, and also an allowance of one pound per square inch for friction, and bends between the gauge and pump-well.

"The duty obtained must be equal to 95,000,000 pounds lifted one foot high for every 100 pounds of coal consumed in the boiler-furnaces during the trial, and said duty shall be reckoned upon the amount of water delivered over the weir at the reservoir, with five per cent. added thereto to allow for loss of action at the pump.

"At the close of the trial the fires to be in as good condition, and the water in the boiler at the same height, and the steam at the same pressure as at the beginning."

In preparation for the test a weir was constructed at the reservoir in the usual form, and with all the appliances of gauge-box, connecting-pipe, and hook-gauge. One side of the gauge-box was made of glass for better illuminating the point of the hook in the night.

The scales for weighing the coal were tested; and for determining the quantity fired at any time it was determined to use the car as provided for the works, running it back to the scales and reweighing after each firing.

By the terms of the contract, the first item to claim the attention of the experts was that "the coal to be used on the trial shall be of the best quality Cumberland coal, and shall be carefully weighed." All the precautions necessary for the careful weighing were taken by us, but the coal was of such quality of Cumberland as could be readily got; its evaporative capacity will be shown by the result of the experiments.

For measuring the water to be supplied to the boilers two tanks were constructed. The upper or measuring tank was a covered box, in the cover of which a small rectangular opening was made for an overflow; 1,400 pounds of water at 45° Fahr. were weighed into it, and by the dropping into the tank three bricks previously well wetted, the level of the water was brought up to the level of the overflow. The lower tank, from which the water was fed into the boilers, was provided with a glass gauge graduated from the upper tank. The graduation was from a full tank downward, so that the water

fed into the boilers was determined from the number of upper tanks discharged plus that drawn from the lower tank.

The steam gauges on boilers and steam and water on engine were those provided by the contractors. The accuracy of the important ones was determined by a comparison of them with a standard gauge of the American Steam Gauge Company, tested by a mercury column.

The thermometers and barometers used were furnished by Huddleston. The thermometers inserted in steam and water passages were made especially for the purpose, the bulbs being enclosed in a tube and the tube inserted into the steam, so that there was no pressure exerted on the bulb. Three thermometers were inserted, one in each of the steam-pipes near the boilers, one in the steam-pipe near the engine, one in each of the jackets of the high and low pressure cylinders, and one in the hot-well delivery-pipe. A tube closed at the lower end and filled with oil was inserted in the main flue for the reception of the thermometer.

A tank with a weir was provided for the reception of the condensed water, and of such capacity as not to be disturbed in its level by the discharge from the hot well.

Indicators were provided and attached to each end of both cylinders, and a pipe connection between the valve chambers of the pump with a T-pipe for the attachment of an indicator.

The gauge for determining the height or pressure of the lift was attached to the air-chamber, the readings were taken hourly, and corrected by comparison with a standard gauge. "The pressure due to the difference of level of this point (the gauge) and the mean surface of the water in the pump-well." A floating gauge was put in the pump-well, and referred to the same base as the gauge in the air-chamber. To determine "the amount of water delivered over the weir at the reservoir" a weir was carefully constructed at the reservoir, observations were taken at no longer intervals than five minutes during the trial, and the quantity estimated by the formula taken from Mr. Francis' "Lowell Hydraulic Experiments."

The Board of experts could have arrived at all the results required by the contract from a careful determination of the amount of coal used, of the pressure in the main referred to the level of the water in the well, and of the amount of water delivered at the reservoir, and following the method prescribed for firing. But it was considered

necessary that other data, usual in such tests, should be obtained, for comparison of these engines with others which have been previously tested under similar circumstances and also to exhibit, and satisfactorily explain, the final results arrived at.

At 4.16 P. M., May 1st, the fires were kindled beneath both boilers. At about 6 P. M. the engine was started, and the weir-box filled, and engine stopped to test the leak in rising main and weir-box. At 8.55 P. M. the engine was again started, and at 1 A. M., May 2d, full observations were commenced. The engine was then run continuously till 12.45 A. M., May 3d, when the pipe which had been inserted into the pump-chambers for the taking of indicator-cards blew out, and the engine was stopped till 2.19 A. M., May 3d, when the engine was again started and observations resumed, and continued without interruption till 2 P. M., May 4th, when your Board decided that the engine had been tested sufficiently, and it was stopped, and preparations made for running the two engines coupled.

The engines were coupled and started, and observations were commenced at 7 A. M., May 5th, and continued without interruption till 6 P. M., May 6th.

Hourly records of observation were made throughout the trial, with the average result* given in the accompanying tabular sheets, on which table I, columns 2 are the points of cut-off of the steam in decimals of the stroke, columns 3 the pressures of steam at the time of cut-off, columns 6 are the points at which compression commences in the exhaust lines in decimals of stroke, and columns 7, the pressures at this point. In this table of indicator cards, the pressures are referred to the zero-line as determined by observations of the barometer referred to the atmospheric line of the indicators. In the last column the net average pressures as determined by the planimeter are given.

Table II, columns 2, 3, 4 and 5, are the net average pressures as determined by the planimeter; column 6 is the reading of the gauge on the main corrected by the subtraction of 0·3 pound, the observed difference between this gauge and the standard; column 7 is the difference of level between the gauge and the hourly-observed level in the well, converting feet into pounds by dividing by 2·31; column 8 is the lift in pounds determined by the terms of the contract; column 9 is the total of coal, and column 10 the total of water as

* In the original report the figures are given as observed for every hour, in extenso.

TABLE No. I—ENGINE B.

TOP OF HIGH-PRESSURE CYLINDER.

Average of hourly observations, 8 A. M. to 12 P. M. (inclusive) May 2d, 1876, = 17 consecutive hours.

Forward Stroke.				Backward Stroke.				At 0·05.		At 0·15		At 0.25.		At 0·35		At 0·45		At 0·55		At 0·65		At 0·75		At 0·85		At 0·95		Net Average.	Planimeter.
Initial.	Cut off at.	Pressure.	Final.	Initial.	Commencement of Compression	Pressure.	Final.	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−		
1.	2.	3	4	5.	6.	7.	8.	9	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22	23.	24.	25.	26	27.	28	29.	30.
99·62	·314	100·2	33·84	29·62	·836	9·19	51·47	100 27	27·1	100 74	10·12	100·72	10·	86·41	10·6	68 05	11·71	56·15	12·98	48·02	14·6	42·14	16·74	37·96	19·38	34 75	24·54	51 79	51·64

Average of hourly observations, 3 A. M. to 7 P.M., May 3d, = 17 consecutive hours; together with same from 5 A.M. to 2 P.M., May 4th, = 10 consecutive hours (omitting one hour). Total, 26 hours.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
100 2	·307	100·4	33·4	28·35	·837	9·35	51·80	101·2	29·51	101·3	10·19	101 03	9·76	86·63	10·35	67·55	11·33	55·63	12·59	47·49	14·23	41·86	16·16	37·65	19·30	34·42	23·78	61·83	52·03

TOP OF LOW-PRESSURE CYLINDER.

Average of hourly observations, 8 A. M. to 12 P. M. (inclusive) May 2d, = 17 consecutive hours.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
26·14			6·14	4·32			......	23·14	1·53	18·74	1·56	15·81	1·69	13·05	1·84	12·17	1·94	10·96	2·07	10·05	2·17	9·24	2·30	8·86	2·49	7·53	2·84	10·96	10·85

Average of hourly observations, 3 A.M. to 7 P.M., May 3d, = 17 consecutive hours; together with same from 5 A.M. to 2 P.M., May 4th, = 10 consecutive hours (omitting one hour). Total, 26 hours.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
26·90			5·95	4·53			......	23·26	1·54	18·78	1·61	15·88	1·65	13·77	1·82	12·18	1·98	11·05	2·05	10·06	2·15	9·30	2·26	8·60	2·43	7·78	2·78	10·97	10·76

BOTTOM OF HIGH-PRESSURE CYLINDER.

Average of hourly observations, 8 A. M. to 12 P. M. (inclusive) May 2d, = 17 consecutive hours.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
103·0	·315	102·4	34·9	28·6	·840	9·9	59·2	102·7	27·3	102·8	10·21	102·9	9·8	91·1	10·2	70·98	10·74	59·9	11·4	50·5	12·9	44·1	14 8	39·7	18·0	36·4	23·0	55·14	55·01

Average of hourly observations, 3 A.M. to 7 P.M., May 3, = 17 consecutive hours; together with five others taken between 9 A.M. and 2 P.M., May 4. Total, 22 hours.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
101·2	·316	101·8	34·8	28·4	·842	8·3	60·92	101 37	26·77	101 67	8·87	101·95	8·68	90·89	9 22	71·36	10·0	59 2	10·19	50·95	12·79	44·56	14 79	40·06	17·91	36·41	22·67	55·67	65·90

BOTTOM OF LOW-PRESSURE CYLINDER.

Average of hourly observations, 8 A. M. to 12 P. M. (inclusive), May 2d, = 17 consecutive hours.

1	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
28 4			6·42	3 44			8·25	22·04	2·74	17·11	1·85	14·17	1·88	12·12	1 9	10·7	2·07	9·72	2·05	3·97	2·14	8·29	2·22	7·76	2·44	7·06	2·67	9·06	9·69

Average of hourly observations, 3 A. M. to 7 P. M., May 3d, = 17 consecutive hours; together with same from 5 A. M. to 2 P. M., May 4th, =10 consecutive hours (omitting one hour). Total, 26 hours.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
28·00			5·98	4·35			......	22·03	2·94	17·20	1·96	14·17	1·94	12·10	1·91	10 69	2·01	9·68	2·10	8·91	2·21	8·19	2·31	7·69	2·38	7·07	2·78	9·51	9·50

TABLE No. II.

Averages and Totals, 3 A. M. to 12 P. M. (inclusive) May 2d. = 22 consecutive hours.

Revolutions by Counter.	High-Pressure Cylinder. Top.	High-Pressure Cylinder. Bottom.	Low-Pressure Cylinder. Top.	Low-Pressure Cylinder. Bottom.	Gauge on Main in lbs.	Water Well below Gauge in lbs.	Total in lbs. + (1 lb. added).	Coal in furnaces, lbs.	Water fed into Boilers lbs.	Level of Water in Boilers in inches.	Temperature of Feed Water Deg. Fahr.	Pressure in Boilers in lbs.	Discharge into Reservoir in gallons.	Lift from Well into Reservoir.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
21444	51·65	55·01	10·82	9·59	64·7	10·40	75·96	7266	60850	6·65	99	90	4527340	168·48

Averages and Totals, 4 A. M. May 3d. to 2 P. M. May 4th, = 35 consecutive hours.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	16.
34218	51·88	55·69	10·86	9·60	64·5	10·60	75·79	11630	95100	6·60	101	90	7261209	168·91

TABLE No. III.

	Gauges.				Temperatures.							Hygrometer.			Barometer.	
	At Engine.		Boilers.													
	Steam lbs.	Vacuum inches.	No. 1. lbs.	No. 2. lbs.	Steam-pipe, D. Fahr.	High-Pressure Cylinder Jacket.	Low Pressure Cylinder Jacket.	In Flues.	Outside Atmosphere.	Boiler-House.	Water in Pump Well.	Wet Bulb.	Dry Bulb.	Humid.	Thermometer attached.	Barometer.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	19.	11.	12.	13.	14.	15.	16.
Practical Greatest,	93	28	94	94	332	331	328	410	58	77	48	66	72	77	57	30·26
" Least,	86	27	86	86	328	328	323	240	32	68	45	68	63	64	44	29·63
" Average,	89·5	27·5	90	90	330	330	326	325	45	72·5	46·5	62	67	70	60·5	29·94

it was fed upon the grates or into the boiler from hour to hour; column 11 was the hourly-observed level of the water in the boiler, referred to the crown-sheets of the fire-box instead of to the usual standard of a zero of common water level.

Column 14 is the hourly discharge of gallons of water into the reservoir as measured at the weir.

Column 15 is the absolute static height of the water over the weir above the level of the water in the pump-well. The crest of the weir and the gauge in the well were referred to the same base, and the column is made up from the hourly observations.

The footings of columns 2, 3, 4, 5, 8 and 15, are averages; of 9, 10 and 14, totals of pounds of coal used, of water fed, and of gallons of water delivered into the reservoir.

By the contract the coal was to be Cumberland, and the kind furnished was supposed to be of good quality; but, during the progress of the test, the evaporative results not being satisfactory, another lot was substituted, and fired from 5 P M., May 3d, to 11 A.M., May 6th, with but little improvements in results. The ashes and cinders were weighed—978 pounds in the single engine tests, 435 pounds during the time the engines were coupled.

Table III gives the observations as taken of the pressure of gauges, temperatures by thermometers, saturation of atmosphere, and pressure by barometer. The caption sufficiently explains the position of the instruments. All the steam gauges were tested by Mr. Moore, of the American Steam Gauge Company; the one on the engine was verified by us, and found to be one pound short in the range from 80 to 95 pounds, so that one pound should be added to the readings in column one.

The thermometer in the flue indicated too low a temperature for the escaping gases, and 4 P.M., May 2d, all air-cracks into the flues were carefully closed.

It was thought advisable that the specific gravity of the water should be tested, which was done by Mr. Maurice Hasenclever, who reports as follows:

Specific gravity of Water as taken from the Engine-house.
Temperature 60° F.
(Compared with distilled water and 60° F. being 1·00000.)
Specific gravity = 1·004871.

$$\left.\begin{array}{r}\text{Specific gravity of Reservoir Water}\\ \text{Temp. } 57^\circ\end{array}\right\} = 1{\cdot}005119.$$

The difference of 0·000245 is very near what theory allows for 3° F. expansion.

Observations were made of the flow at the condensed water weir at different times when the water was not directed into the measuring tank for the feeding of the boiler. The results, as given below, are in pounds per second:

May 2,	2.15	to	2.45	A.M.	10·86 lbs.	
"	4.20	"	4.45	"	11·32 "	at 101°
"	12.8	"	12 31	P.M.	11·41 "	" 101°.
"	2.30	"	2.52	"	11·11 "	" 99°
"	4.	"	4.17	"	10·71 "	" 103°
"	10.7	"	10.31	"	11·16 "	
May 3,	4.10	"	5.25	A.M.	11·45 "	
"	10.57	"	11.47	"	10·92 "	
"	2.15	"	3.	P.M.	10·82 "	" 106°
"	3.	"	4.	"	10·59 "	" 109°
"	4.	"	5.	"	10·43 "	" 106°
"	5.	"	6.	"	10·34 "	" 106·5°
"	6.	"	6.45	"	10·39 "	" 106·5°
May 4,	3.40	"	3.50	A.M.	10·26 "	" 104 5°
"	6.2	"	6.15	"	10·58 "	" 105°
"	9.	"	9.32	"	10·13 "	" 106·5°
"	10.50	"	11.50	"	10.29 "	" 106·75°

CALCULATION FROM THE DATA OBTAINED.—*Duty per pound of coal in the steam cylinders, estimated from the indicator card:*

Diameter of high-pressure cylinders, . . .	18″ area,	254·47 sq. in.
This will be effective area of bottom of piston; of the top it will be less the area of piston rod, or 254·47—9·62, . . .		244·85 "
Diameter of low-pressure cylinder, . . .	38″ area,	1134·11 "
Top area of piston, 1134·11—12·57, . .		1121·54 "

During the 22 hours, from 2 A.M. to 12 P.M., May 2d, the average pressures by planimeter, Table V, were:

Top of high pressure cylinder, ...	51·65
Bottom " " "	55·01
Top of low " "	10·82
Bottom " " "	9·59

Top high pressure,	51·65 × 244·85 =	12646·5	
Bottom " "	55·01 × 254·47 =		13998·4
Top low pressure,	10·82 × 1121·54 =	12135·1	
Bot. " "	9·59 × 1134·11 =		10876·1
		24781·6	24874·5	49656·1

The length of stroke was 8 feet, the number of revolutions, 21,444, and coal consumed, 7.266 pounds.

$$\frac{49656{\cdot}1 \times 21444 \times 8}{7266} = 1{,}172{,}365 \text{ pounds feet per pound of coal;}$$

since 1 H. P. = 1.980,000 pounds feet per hour.

$$\frac{1{,}980{,}000}{1{,}172{,}365} = 1\ 69.$$

That is, 1 indicated horse power for every 1·69 pound of coal fed upon the grates.

During the 35 hours. from 3 A.M., May 3d, to 2 P M., May 4th, the average pressures in the steam cylinders were:

Top of high pressure cylinder, . . .	51·88
Bottom " " " . . .	55·69
Top of low " " . . .	10·86
Bottom " " " . . .	9·60

Top high pressure,	51·88 × 244·85 =	12702·8		
Bot. " "	55·69 × 254·47 =		14171·4	
Top low pressure,	10·86 × 1121·54 =	12179·8		
Bot. " "	9·6 × 1134·11 =		10887·4	
		24882·6	25058·8	49941·4

The number of revolutions was 34,218, coal consumed, 11,630 pounds.

$$\frac{49941{\cdot}4 \times 34218 \times 8}{11630} = 1.175{,}508 \text{ pounds feet per pound of coal;}$$

$$\frac{1{\cdot}980{\cdot}000}{1175508} = 1{\cdot}684 \text{ pounds per hour, per 1 indicated H. P.}$$

In the early part of this report the duty per pound of coal determined by the terms of the contract on the main was:

For the 22 hours, ...	962·019 pounds feet.
" 35 "	961·776 " "

During the 34 hours of trial of the engines running coupled, the average pressure was 77·73 pounds; the gallons discharged into the reservoir, 11,450,593; coal consumed, 18,411.

$$1{\cdot}05 \times \frac{(77{\cdot}73 \times 2{\cdot}31) \times (11450593 \times 8{\cdot}38)}{18411} = 982617 \text{ pounds feet}$$

per pound of coal.

Comparison of the static head of the water over the weir above the level of the water in the well, with the head determined according to the terms of the contract:

For 22 hrs., May 2,	Static head,	.	168·48
	Contract,	. .	$75·96 \times 2·31 = 175·47$
" 35 " " 3 and 4,	Static head,	.	168·91
	Contract,	. .	$75·79 \times 2·31 = 175·07$
" 34 " " 5 and 6,	Static head,	.	169·66
	Contract,	. .	$77·73 \times 2·31 = 179·56$

Comparison of the measured capacity of the pump with the delivery into the reservoir.—No measurements of the interior of the pump-barrels were taken by the experts. The measures have been taken from the notes of Mr. Leavitt. Diameter of pump-bucket, $26\frac{1}{8}$ inches; area, 536·05; stroke, 96 inches.

$$\frac{536·05 \times 96}{231} = 222·77 \text{ gallons per revolution.}$$

In the 22 hours, $\frac{4527340 \text{ galls.}}{21444 \text{ revols.}} = 211·12$ gallons per revolution; ·948 of measured capacity.

In the 35 hours, $\frac{7261209 \text{ galls.}}{34218 \text{ revols.}} = 212·2$ gallons; ·952 measured capacity.

In the 34 hours, $\frac{11450593}{27248 \times 2} = 210·11$ galls.; ·943 measured capacity.

Evaporation.—The quantities of water measured at the tanks are not exactly the quantities evaporated in the boilers, as it will be observed that the levels of water in the boilers are not the same at the ends of the tests as at the beginning. A correction must therefore be applied.

For the data for this calculation there was assumed a uniform pressure in the boiler of 90 pounds, 330° of temperature, of feed-water of 100°, of total in steam, 1214°, in all the tests. The cubic contents of each boiler, for the single inch between 6″ and 7″, we estimate at 10 cubic feet, and the weight at 605 pounds. In the 1st and 3d tests the level of water in the boiler at the end of tests was 5″ and 7″ higher than at the beginning, or there were 605 pounds in one, and 847 pounds in the other, more than at the beginning, which was not evaporated, but had been raised from the temperature of feed-water, 100°, to temperature of water in boiler, 330°; the net deduction we therefore make 480 pounds.

In the 3d test, in the same way, we make the net deduction to be 672 pounds.

In the 2d test, 35 hours, the water in the boiler at the end of the test was 1·5″ lower than in the beginning; 1210 × 1·5; 1815 pounds had been evaporated, which had not during the test been measured in the tanks. But this water had not been evaporated from the temperature of the feed-water, 100°, but from that of the boiler water, 330°, equivalent to 1440 pounds evaporated from 100°, which should be added to amount given in the table.

The water was weighed into the measuring tank at 45°, and taken from it for the boilers at 100°. The last columns are the pounds of water corrected for this difference in temperatures.

	Coal.	Water from Tanks.	Correction.	Water Evaporated from 100°.		
				Total.	Per Pound of Coal.	Actual Evaporation per Pound of Coal.
1st test 22 hrs.	7,266	60,852	—480	60,370	8·31	8·27
2d " 35 "	11,630	95,100	+1,440	96,540	8·31	8·27
3d " 34 "	18,411	161,330	—672	160,658	8·73	8·69

At the time of the tests, the preparations were not sufficiently complete to measure the water condensed in the jackets, and this was made the subject of an after examination by Mr. Hoadley, May 23d, using the tank for water of condensation as a measure. Reading by the hook gauge, he found that from 11 A.M. to 5 P.M. the water rose from ·0155 foot to 1·7700 or 1·7545 feet, or at the rate of ·2924 foot per hour for 6 hours. The area of tank, including gauge-box, was 19·186 square feet. The mean temperature of water, 188°; weight per cubic foot, 60·4167 pounds.

$$19186 \times \cdot 2924 \times 60 \cdot 4167 = 338 \cdot 85 \text{ pounds per hour,}$$

as the water condensed in the jackets of the cylinders, engine B.

But exactly the same conditions did not obtain as during the test. The pressure carried in the boilers at this time was from 70 to 75 pounds, and the observed temperature in the low-pressure cylinder jacket at 75 pounds was 315°. At the time of test there was an average of about 326° under 90 pounds pressure.

Coal Consumed per Hour per Square Foot of Grate.—During the 1st and 2d tests, of 22 hours and 35 hours, although both boilers were used, the grate surfaces were reduced by a brick bridge on the rear of the bars, which were removed in the 3d test, when the engines

ran coupled. The net area of grate surface in the 1st and 2d tests was 47 square feet; in the 3d, $58\frac{3}{4}$ square feet.

Coal Fed per Hour.—

1st test, $\frac{7266}{22} = 330{\cdot}3 \quad \frac{330{\cdot}3}{47} = 7{\cdot}03$ pounds per sq. foot of grate.

2d " $\frac{11630}{35} = 332{\cdot}3 \quad \frac{332{\cdot}3}{47} = 7{\cdot}07$ " " " "

3d " $\frac{18411}{34} = 541{\cdot}5 \quad \frac{541{\cdot}5}{58{\cdot}75} = 9{\cdot}22$ " " " "

Comparison of curves as given by the indicator with theoretical, adiabatic, and isothermal curves. A set of indicator cards, from both ends of both cylinders, were very carefully divided and measured by Mr. Hoadley, of our Board, and replotted, the low pressure cylinder at bottom, in connection with high pressure bottom, and the low pressure top with high pressure top, all volumes being represented in the terms of volumes of high pressure cylinder. On these cards, thus constructed, isothermal and adiabatic curves and lines of temperatures are plotted. The indicator cards and comparative cards are given in the accompanying figures, with the tables of volumes, temperatures, and pressures, on which the comparative cards were constructed, and which will be sufficiently explanatory of each other.

The Board of Experts report, as the result of their examination, as to the fulfilment of the requisitions of the contract, that: From 2 A.M. to 12 midnight, May 2d, 22 hours, there were delivered into the reservoir, as measured by the weir observations taken at intervals of not more than five minutes, 4,527,340 gallons,

or 2,057,881 gallons for each ten hours.

Revolutions, 16·25 per minute; boiler pressure, 90 pounds.

From 3 A.M., May 3d, to 2 P.M., May 4th, 35 hours, the delivery into the reservoir, measured as before, was 7,261,209 gallons,

or 2,074,681 gallons for each ten hours.

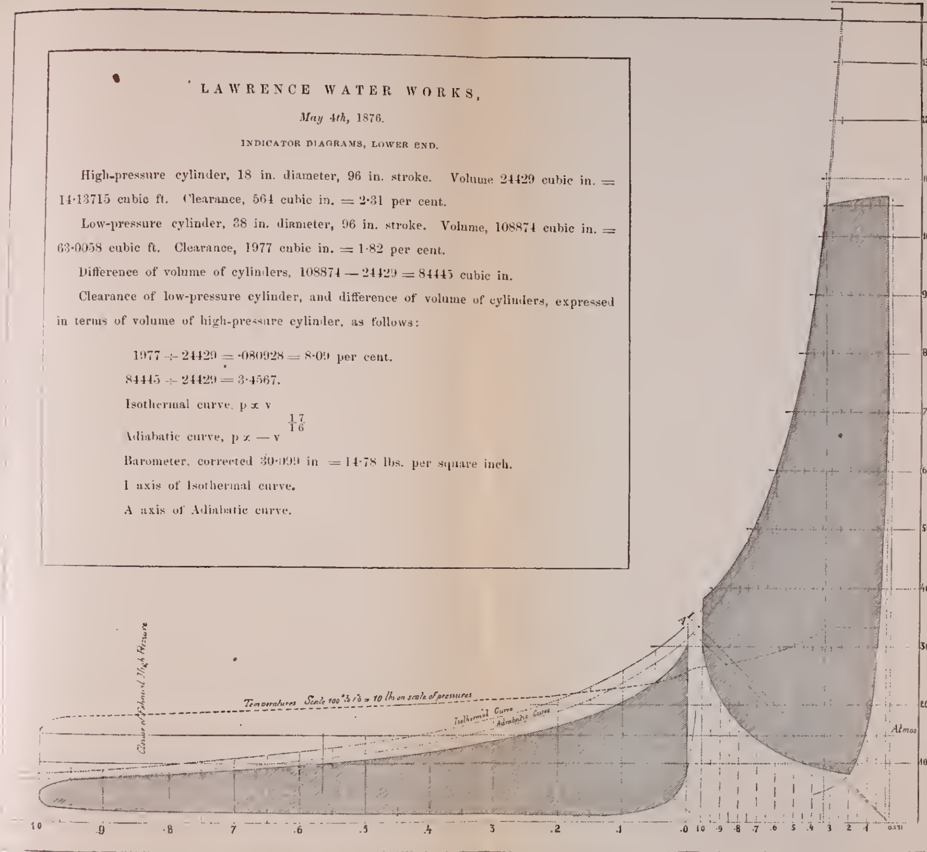
Revolutions, 16·29; boiler pressure, 89 pounds.

The contract is for

2,000,000 gallons in ten hours for each engine,

with a speed of 16 revolutions per minute, and a steam pressure in boiler of 90 pounds per square inch.

Duty.—The lift, as determined by the terms of the contract, was in the 22 hours' test of May 2d, 75·96 pounds, or $75{\cdot}96 \times 2{\cdot}31 = 175{\cdot}47$ feet.



LAWRENCE WATER WORKS,

May 4th, 1876.

INDICATOR DIAGRAMS, LOWER END.

High-pressure cylinder, 18 in. diameter, 96 in. stroke. Volume 24429 cubic in. = 14·13715 cubic ft. Clearance, 564 cubic in. = 2·31 per cent.

Low-pressure cylinder, 38 in. diameter, 96 in. stroke. Volume, 108874 cubic in. = 63·0058 cubic ft. Clearance, 1977 cubic in. = 1·82 per cent.

Difference of volume of cylinders, 108874 — 24429 = 84445 cubic in.

Clearance of low-pressure cylinder, and difference of volume of cylinders, expressed in terms of volume of high-pressure cylinder, as follows:

1977 ÷ 24429 = ·080928 = 8·09 per cent.

84445 ÷ 24429 = 3·4567.

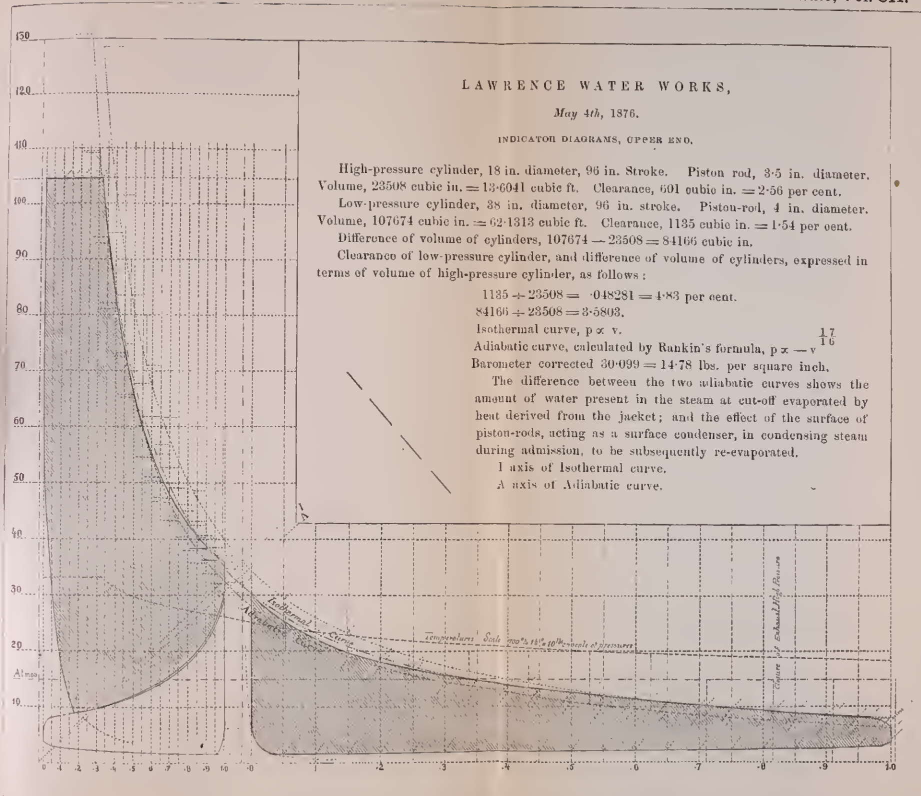
Isothermal curve, $p \propto v$

Adiabatic curve, $p \propto — v^{\frac{17}{16}}$

Barometer, corrected 30·099 in = 14·78 lbs. per square inch.

I axis of Isothermal curve.

A axis of Adiabatic curve.


LAWRENCE WATER WORKS,
May 4th, 1876.
INDICATOR DIAGRAMS, UPPER END.
High-pressure cylinder, 18 in. diameter, 96 in. Stroke. Piston rod, 3·5 in. diameter. Volume, 23508 cubic in. = 13·6041 cubic ft. Clearance, 601 cubic in. = 2·56 per cent.
Low-pressure cylinder, 38 in. diameter, 96 in. stroke. Piston-rod, 4 in. diameter. Volume, 107674 cubic in. = 62·1313 cubic ft. Clearance, 1135 cubic in. = 1·54 per cent.
Difference of volume of cylinders, 107674 — 23508 = 84166 cubic in.
Clearance of low-pressure cylinder, and difference of volume of cylinders, expressed in terms of volume of high-pressure cylinder, as follows:
$1135 \div 23508 = \cdot 048281 = 4 \cdot 83$ per cent.
$84166 \div 23508 = 3 \cdot 5803$.
Isothermal curve, $p \propto v$.
Adiabatic curve, calculated by Rankin's formula, $p \propto - v^{\frac{17}{16}}$
Barometer corrected 30·099 = 14·78 lbs. per square inch.
The difference between the two adiabatic curves shows the amount of water present in the steam at cut-off evaporated by heat derived from the jacket; and the effect of the surface of piston-rods, acting as a surface condenser, in condensing steam during admission, to be subsequently re-evaporated.
I axis of Isothermal curve.
A axis of Adiabatic curve.
130
120
110
100
90
80
70
60
50
40
30
20
Atmos
10
Isothermal Curve
Adiabatic Curve
Temperatures Scale
Exhaust High Pressure

The amount of water delivered at the reservoir was, as above stated, 4,527,340 gallons. The weight of a gallon of water, from the specific gravities taken by Mr. Hasenclever, we estimate at 8·38 pounds, 4,527,340 gallons + 5 per cent., as per terms of contract = 4,753,707 × 8·38 pounds = 39,836,064 pounds.

The coal consumed during the time, 7,266 pounds:

$$\frac{175{\cdot}47 \times 39836064}{7{,}266} = 962{,}019 \text{ pounds feet}$$

for the duty of one pound of coal.

In the 35 hours' test of May 3d and 4th, the lift was 75·79 pounds = 175·07 feet.

The amount delivered at the reservoir was 7,261,209 gallons, and plus 5 per cent. = 7,624,269 gallons, or 63,891,374 pounds.

The coal consumed during the time 11,630 pounds:

$$\frac{175{\cdot}07 \times 63{,}891{,}374}{11{,}630} = 961{,}776 \text{ pounds feet}$$

for the duty of one pound of coal.

The duty to be obtained by the contract must be equal to 95,000,000 pounds lifted one foot high for every 100 pounds of coal consumed in the boiler furnaces. Both results above are in excess of the requirements. The average of the two, or fifty-seven hours, gives 96,186,979 pounds lifted one foot high by 100 pounds of coal.

In conclusion, it has been our aim to give as fully as possible all the data acquired and facts arrived at, with such deductions as were necessary by the terms of the contract, or explanatory of the working of the engine, and readily comparative with the results of others. With regard to material and workmanship, the engines are strong, compact, well made, and, in disposition of material, good examples of mechanical engineering, and in their future working we feel sure that they will be serviceable and economical, and that the duty now arrived at could be readily surpassed after longer working and acquaintance with the machines and their appliances.

Yours, respectfully,

(Signed) W. E. WORTHEN,
J. C. HOADLEY,
JOS. P. DAVIS.

ENGINE B.—UPPER END.

MAY 6, 1876, 11.30 A.M. ELLIOTT INDICATORS. BAROMETER, CORRECTED, 30·099 IN. = 14·78 LBS.

PART OF STROKE.	Volumes in terms of Volume of High-Pressure Cylinder.	Measured ordinates, Pressures absolute.	Temperature, Fahrenheit.	Adiabatic curve begun at cut-off, P. 104·7.	Isothermal curve begun at cut-off, P. = 104·7	Adiabatic curve begun at 11 times the fill, P. = 10·09.	
0·0	·0256	104 7	330 9°	....	....	....	
0·5	·0756	104·7	330 9	....	....	....	
·1	·1256	104·7	330·9	....	....	....	
·15	·1756	104 7	330 9	....	....	....	
·2	·2256	104·7	330 9	161 7	157·6	....	
·25	·2706	104 7	330 9	130 7	129·0	....	
·3	·3256	104 7	330 9	109 5	109 2	....	
Cut-off.....	·3396	(104·7)	(330 9)	104·7	104·7	1 = 128·6	(Cut-off)
·35	·3756	93 0	332·4	94·1	94·7	1¼ = 101·4	
·4	·4256	81 1	312·8	82·4	83·5	1½ = 83·6	
·45	·4756	72·6	305 2	73 2	74·8	1¾ = 70·9	
·55	·5256	65·5	298 3	65 8	67·7	2 = 61·6	(Exactly 0·65 H.P.)
·55	·5756	60 0	292·5	59·8	61·8	2¼ = 54·3	
·65	·6256	55·1	287 0	54·7	56·8	2½ = 48·6	
·65	·6756	51·2	282 3	50·4	52·6	2¾ = 43·9	
·7	·7256	47 6	279 8	46 7	49·0	3 = 40·0	{ (Very near Level H. P. = 1·0256)
·75	·7756	44 9	294·2	43 5	46·0	....	
·8	·8256	42 3	270 5	40 7	43·1	4 = 29·5	(Very near 0·05 L.P)
·85	·8756	40·2	267 4	38 3	40 6	....	
·9	·9256	38 4	264 7	36 1	38·4	5 = 23·25	(Very near 0·15 L.P)
·95	·9756	37 0	262 5	34·1	36·5	....	
1·0	1·0256	35 8	230 5	32 4	34·7	6 = 19·2	
Means.....	....	71·37	{ 300·285 lbs. = 57·5	....	....	....	

....	....	....	....	....	....	7 = 16·3	
....	....	....	....	....	....	8 = 14·1·	
....	....	....	....	....	....	9 = 12·45	
Cross Pipe	1·1248	....	....	29·3	31·6	....	
0·0	1·1731	29·9	249·4	28·1	30·3	10 = 11·1	
·05	1·3521	24·9	239·8	24·1	26·3	....	
·1	1·5311	21·7	232·3	21·1	23·2	11 = 10·06	Starting-point.
·15	1·7101	19·5	226·6	18 8	20·8	....	
·2	1·8892	17 8	221·8	16 9	18 8	12 = 9·17	
·25	2·0682	16·3	217·2	15·4	17·2	....	
·3	2·2472	15·2	213·7	14·1	15 8	13 = 8·42	
·35	2·4262	14·1	209·9	13·0	14·7	....	
·4	2·6052	13·3	207·0	12·0	13·6	14 = 7·79	Near end of diagram.
·45	2·7842	12 6	204·3	11·2	12·8	....	
·5	2 9633	11·9	201·5	10·5	12·0	....	
·55	3·1423	11·4	199·4	9·9	11·3	....	
·6	3·3213	10·9	197·3	9·3	10·7	....	
·65	3·5003	10·5	195 5	8·8	10·2	....	
·7	3·6793	10·1	193 6	8·3	9·7	....	
·75	3·8583	9·7	191·8	7 9	9·2	....	
·8	4·0373	9·3	189·8	7·5	8 8	....	
·85	4·2164	8 9	187·8	7·2	8·4	....	
·9	4·3954	8·5	185 6	6·9	8·1	....	
·95	4·5744	8·2	184 0	6·6	7·8	....	
Return....	4·5903	(8·0)	....	....	....	....	
1·0	4·7534	5·4	165·4	6·3	7·5	(At 4·7576)	
Means.....	....	14·1425	{ 205·315 = 12·855 lbs.	....	....	....	

ENGINE B.—LOWER END.

MAY 6, 1876, 11.30 A.M. ELLIOTT INDICATORS. BAROMETER, COUNTED, 30·099 IN. = 14·78 LBS.

PART OF STROKE.	Volumes in terms of Volume of High-Pressure Cylinder.	Measured ordinates, Pressures absolute.	Temperatures, Fahr., °.	Adiabatic curve begun at cut-off = vol. = ·35 P. = 105·3.	Isothermal curve begun at cut-off, P. = 105·3.
0·0	·0231	106·6	332·2	....	....
·05	·0731	106 6	332·2	....	....
·1	·1231	106·5	332·1	....	....
·15	·1731	106·3	332·0	....	....
·2	·2231	106·0	331·8	172·5	167·6
·25	·2731	105·6	331·5	139·1	136·9
·3	·3231	105·4	331·4	116·4	115·7
Cut-off.......	·3500	105·3	....	105·3	105·3
·35	·3731	99·5	327·2	99·9	100·0
·4	·4231	87·4	317·0	87·4	88·4
·45	·4731	78·5	310·5	77·6	79·0
·5	·5231	71·0	303·7	69·7	71·5
·55	·5731	65·0	297·8	63 3	65·2
·6	·6231	59 9	292·4	57·9	60·0
·65	·6731	55·6	287·6	53·4	55·5
·7	·7231	51·9	283 2	49·5	51·7
·75	·7731	48·4	278 8	46·1	48·8
·8	·8231	45·6	275·1	43·1	45·4
·85	·8731	43·4	272·1	40·5	42·8
·9	·9231	41·2	268·9	38·2	40·5
·95	·9731	39·4	266·2	36·1	38·4
1·0	1·0231	38·0	264·0	34·2	36·5
Means.......	....	74·775	{ 303·48 = 70·80 lbs.	....	....

PART OF STROKE.	Volumes	Pressures	Temperatures	Adiabatic	Isothermal
0·0	1·1040	30·9	251·6	31·5	33·9
·05	1·2768	23·7	237·1	27·0	29·3
·1	1·4497	20·3	230·3	23·6	25·8
·15	1·6225	18 9	224·9	21·0	23·0
·2	1·7953	16·1	216·6	18·8	20 8
·25	1·9682	14·7	212·0	17·1	19·0
·3	2 1410	13·5	207·7	15·6	17·5
·35	2·3138	12·6	204·3	14·4	16·2
·4	2·4867	11·7	200·7	13·3	15·0
·45	2·6595	11·1	198·2	12·4	14·1
·5	2·8324	10·4	195·1	11·6	13·2
·55	3·0052	9·9	192·7	10·9	12·4
·6	3·1780	9·4	190·3	10·3	11 8
·65	3·3509	9·0	188·3	9·7	11·2
·7	3·5237	8·6	186·2	9·2	10·6
·75	3·6965	8·4	185·1	8·7	10·1
·8	3·8694	8·0	182·9	8·3	9·7
·85	4·0422	7·7	181·1	7·9	9·3
·9	4·2150	7·4	179·7	7·6	8·9
·95	4·3897	7·0	176·9	7·3	8·5
Return......	4·4104	(6·8)	....	....	....
1·0	4·5607	4·1	154·0	7·0	8·2
Means.......	....	12·295	{ 199·645 = 11·45 lbs.	....	....

ENGINE B—UPPER AND LOWER ENDS—EXHAUST LINE.

MAY 6, 1876, 11.30 A.M. ELLIOTT INDICATORS.

PARTS.	UPPER END. Measured Volumes.	UPPER END. Measured Pressures.	Temperature, °		LOWER END. Measured Volumes.	LOWER END. Measured Pressures.	Temperatures, °	
0·0	·0256	63·0	295·7	0·0	·0231	75·5	307·8	
·05	·0756	31·5	253·1	·05	·0731	29·2	248·7	
·1	·1256	17·7	220·8	·10	·0231	15·2	213·7	
·15	·1756	11·4	199·4	·15	·1731	9·6	191·3	
Closure..........	·2006	(9·2)	....	Closure.	·1888	(8·5)	....	
·25	·2256	9·3	190·1	·2	·2231	8·3	184·5	
·25	·2756	9·7	192·5	....	·2731	8·5	185·6	
·3	·3256	10·1	193·7	·3	·3231	8·7	186·7	
·35	·3756	10·5	195·5	....	·3731	9·0	188·3	
·4	·4256	10·9	197·4	·4	·4231	9·5	190·8	
·45	·4756	11·5	199·9	....	·4731	10·0	193·2	
·5	·5256	12·1	202·4	·5	·5231	10·5	195·5	
·55	·5756	12·8	205·1	....	·5731	11·2	198·6	
·6	·6256	13·6	208·1	·6	·6231	11·9	201·5	
·65	·6756	14·6	211·6	....	·6731	12·9	205·5	
·7	·7256	15·7	215·3	·7	·7231	14·0	209·6	
·75	·7756	16·9	219·1	....	·7731	15·2	213·7	
·8	·8256	18·3	223·2	·8	·8231	16·8	218·8	
·85	·8756	20·1	228·2	....	·8731	18·9	224·9	
·9	·9256	22·2	233·5	·9	·9281	21·0	230·5	
·95	·9756	25·3	240·7	....	·9731	24·2	238·2	
1·0	1·0206	30·5	251·2	1·0	1·0231	31·0	252·1	
Means[1]..........	......	17·0475	{ 215·2775 = 15·70 lbs.	....	......	15·8925	{ 209·9775 = 14·12 lb. }	215·28 209·98 2)425·26
Means of both ends..........	......	......	212·63	....	......	......		212·63
Jackets..........	......	......	330·90	....	......	......		330·96
Difference..........	......	......	....	....	......	......		118·33
Cross Pipe.......	1·1248	......	....	....	......	......	....	
0·0	1·1731	5·9	169.3	0·0	1·1040	8·6	186·8	
Closure..........	1·2231	(1·6)	....	....	......	......	....	
·05	1·3521	1·6	116·6	0·5	1·2768	2·3	130·9	
....	......	......	....	Closure.	1·3563	(1·4)	....	
·1	1·5311	1·6	116·6	·1	1·4497	1·4	111·7	
·15	1·7101	1·6	116 6	....	1·6225	1·3	109·3	
·2	1·8892	1·7	119·0	·2	1·7953	1·3	109·3	
·25	2·0682	1·7	119·0	....	1·9682	1·3	109·3	
·3	2·2472	1·7	119·0	·3	1·1410	1·4	111·7	
·35	2·4262	1·7	119·0	....	2 3138	1·4	111·7	
·4	2·6052	1·8	121·4	·4	2·4867	1·4	111·7	
·45	2·7842	1·9	123·8	....	2·6595	1·5	114·1	
·5	2·9633	1·9	123·8	·5	2·8324	1·5	114.1	
·55	3·1423	2·0	126·3	....	3 0052	1·5	114·1	
·6	3·3213	2·1	127·8	·6	3·1780	1·5	114·1	
·65	3·5008	2·2	129·3	....	3·3509	1·6	114·1	
·7	3·6793	2·3	130·9	·7	3·5237	1·6	116·6	
·75	3·8583	2·3	130·9	....	3·6965	1·7	119·0	
·8	4·0373	2·4	132·4	·8	3·8694	1·8	121·4	
·85	4·2164	2·5	133·9	....	4·0422	1·9	123·8	
·9	4·3954	2·6	135·5	·9	4·2150	2·0	126·3	
·95	4·5744	2·8	138·6	....	4·3879	2·2	129·3	
....	4·7060	3·1	150·8	....	4·5089	2·5	....	
1·0	4·7538	3·8	....	1·0	4·5607	3·2	143·9	
Means..........	......	2·1625	{ 127·0225 = 2·05 lbs.	....	......	1·825	{ 118·5175 = 1·68 lb. }	127·02 118·52 2)245·54
Means of both ends..........	......	......	....	....	......	......		122·77
Jackets..........	......	......	....	....	......	......		330 96
Difference.......	......	......	....	....	......	......		208·19

Fig. 1.

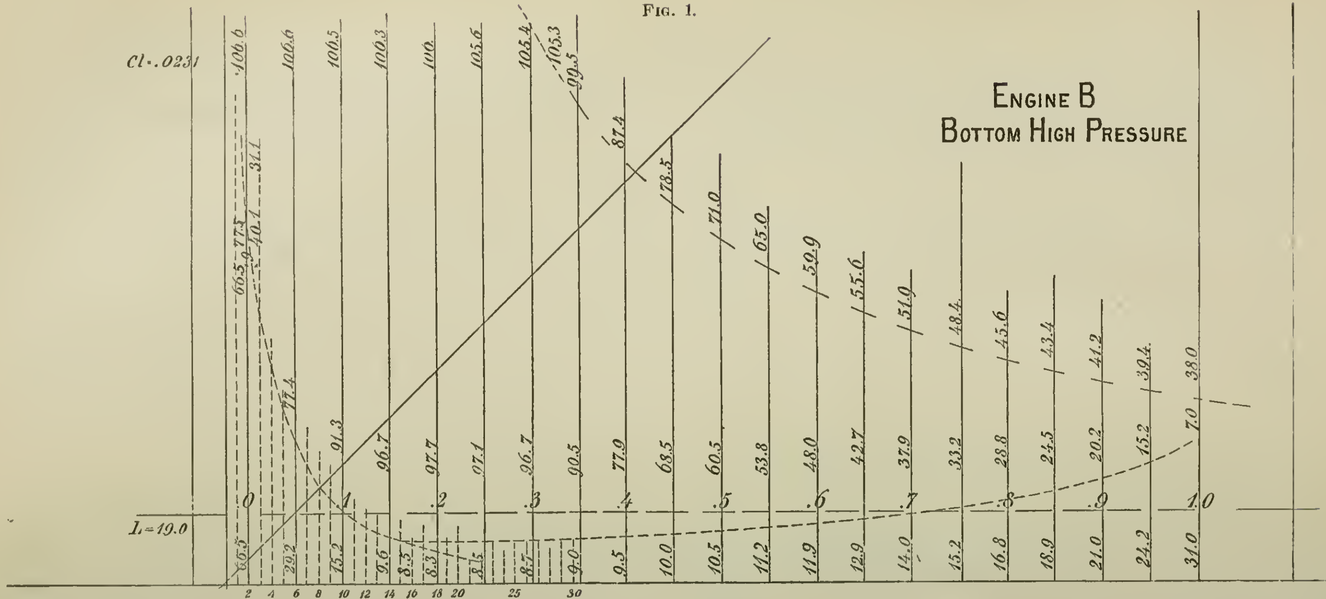


Fig. 2.

Engine B
Bottom Low Pressure

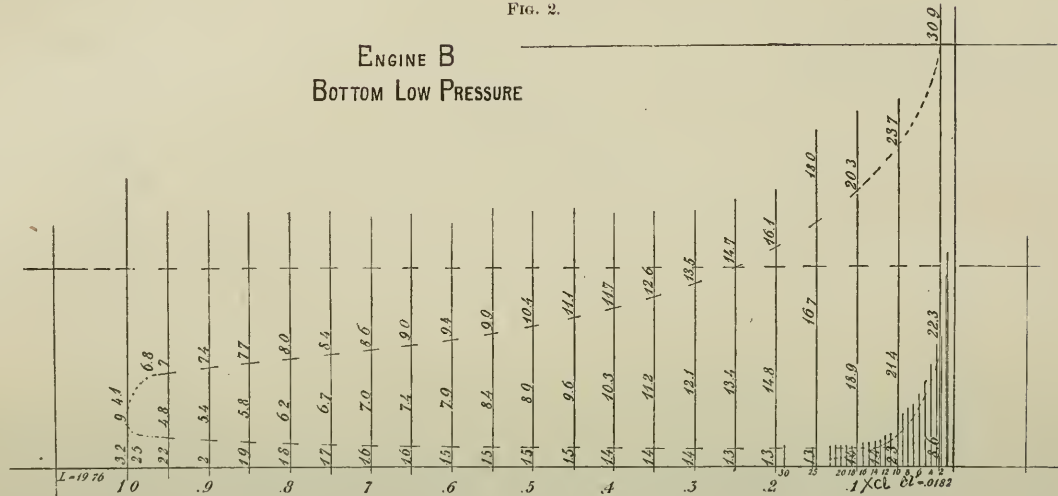


Fig. 3.

Engine B
High Pressure Top

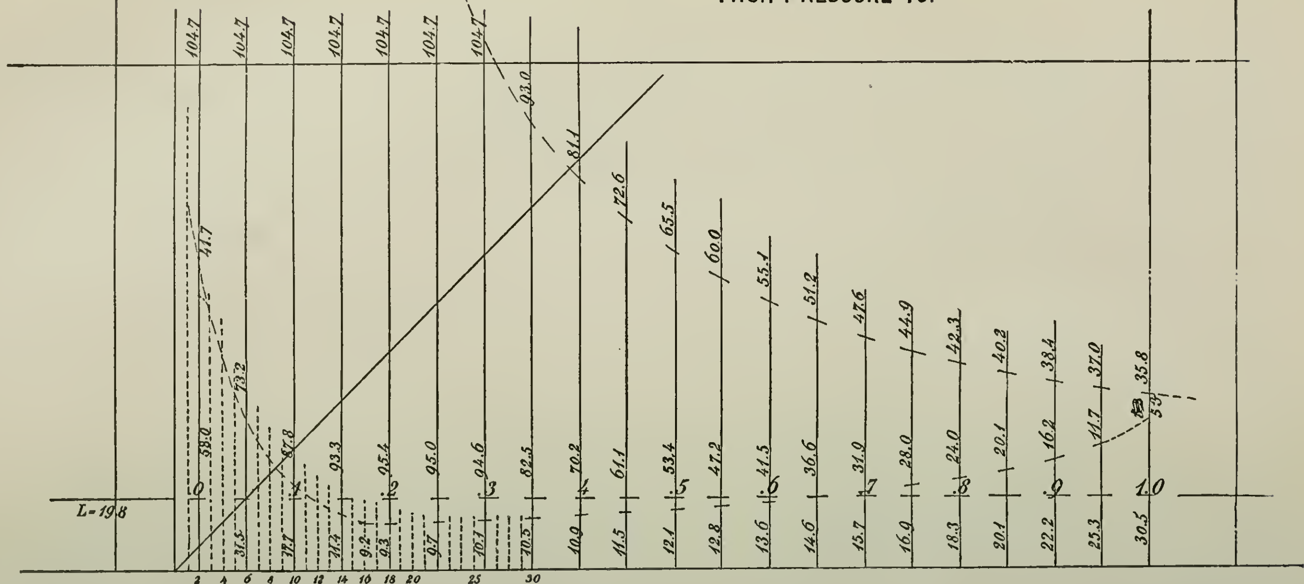
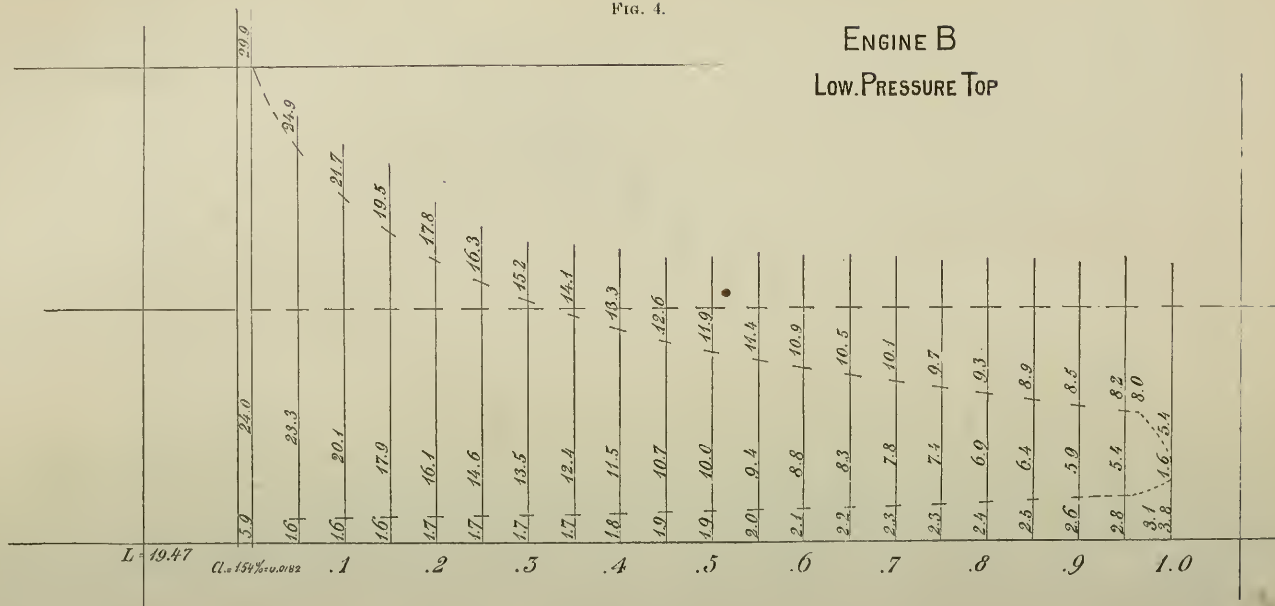


Fig. 4.



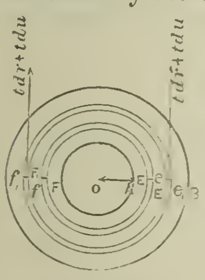
DEMONSTRATION OF LAMÉ'S FORMULA FOR THE STRENGTH OF THICK HOLLOW CYLINDERS

SUBJECTED TO UNIFORM NORMAL PRESSURE.

By GAETANO LANZA, Prof. Mass. Institute of Technology.

The widely differing results obtained by the use of the various formulæ for the thickness of the walls of hydrostatic presses (thick hollow cylinders) seem to render it desirable that in the case of a formula which is as reliable as Lamé's*, a demonstration should be given which could be read by a person who has not previously studied the theory of elasticity. This I have endeavored to do in the following article, the steps followed being virtually those taken by Lamé, but all matter foreign to the subject in hand being eliminated.

In this paper the word *strain* is used to indicate the elongation or shortening of a body per unit of length: the force producing it being indicated by the word *stress*.



Let $OA = R =$ inside radius; $OB = R_1 =$ outside radius; let the length of the portion of the cylinder under consideration be unity; let

$P =$ intensity of internal normal pressure;

$P_1 =$ intensity of external normal pressure.

Assume any ring $E\,F\,e\,f$ where $O\,E = r$, $O\,e = r + d\,r$; $p =$ intensity of normal stress on the inside; $p + d\,p =$ intensity of normal stress on the outside; $t =$ intensity of tangential stress.

Suppose that after the pressure is applied the ring $E\,F\,e\,f$ becomes $E_1\,F_1\,e_1 f_1$ where $O\,E_1 = r + u$; $O\,e_1 = r + u + dr + du$ (u being a small quantity).

I. *As to the strains in the radial and in the tangential direction.*

In the radial direction the width $E\,e = d\,r$ has become:

$$E_1\,e_1 = d\,r + d\,u;\ \text{hence the } \textit{strain} \text{ in this direction} = \frac{d\,u}{d\,r}.$$

In the tangential direction the length $2\,\pi\,r$ of the circumference $E\,F$ has become:

$$2\,\pi\,(r + u);\ \text{hence } \textit{strain} \text{ in the tangential direction} = \frac{2\,\pi\,u}{2\,\pi\,r} = \frac{u}{r}$$

* "Leçons sur Elasticité des Corps Solides," par M. G. Lamé.

II. *To determine the relation between p, t, and r consistent with equilibrium.*

Consider the forces acting on the upper half ring $E_1 F_1 e_1 f_1$;

1st, upward force due to internal pressure: $= 2p(r+u)$*;

2d, downward force due to external pressure:

$$= 2(p+dp)(r+u+dr+du);$$

3d, tangential stress (represented as acting upward):

$$= 2t(dr+du).$$

(In the ordinary case when there is no external pressure on the cylinder, dp and p have contrary signs, and $2t(dr+du)$ is a downward force and consequently a hoop tension); hence for equilibrium we must have:

$$2(p+dp)(r+u+dr+du) - 2p(r+u) - 2t(dr+du) = o,$$

or $2pr + 2pu + 2p\,dr + 2p\,du + 2r\,dp + 2u\,dp + 2\,dp\,dr + 2\,dp\,du - 2pr - 2pu - 2t\,dr - 2t\,du = o.$

Cancelling $2pr$ and $2pu$ with $-2pr$ and $-2pu$ and omitting those terms that contain infinitesimals of a higher order than the first, viz.: $2p\,du$, $2u\,dp$, $2\,dp\,dr$, $2\,dp\,du$, $2t\,du$, and dividing by 2, we obtain:

$$p\,dr + r\,dp - t\,dr = o.$$

Dividing by dr, we have $\frac{dp}{dr} + \frac{p-t}{r} = o$ as the desired relation.

III. It is evident that the stresses p and t must depend upon, and therefore be, functions of the strains $\frac{du}{dr}$ and $\frac{u}{r}$; and moreover these functions must be of such a nature as to vanish whenever both $\frac{du}{dr}$ and $\frac{u}{r}$ vanish, since we know that when there are no strains there are no stresses; hence if we express the stresses p and t in series of ascending powers and products of $\frac{du}{dr}$ and $\frac{u}{r}$, the development must not contain any term independent both of $\frac{du}{dr}$ and $\frac{u}{r}$.

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* The total upward force acting on the ring in consequence of the internal normal pressure will be the same as that acting on a section of the cylinder, made by a plane passing through its axis and the diameter $E_1 F_1$. The area of this section will be $2(r+u) \times 1 = 2(r+u)$, hence the total upward force will be $2(r+u) \times p$, or $2p(r+u)$.

Moreover since $\frac{du}{dr}$ and $\frac{u}{r}$ are themselves small quantities, we may omit all powers higher than the first, and all products of these strains, and use as a sufficiently close approximation only those terms containing their first powers; hence we may write

$$p = \alpha\left(\frac{du}{dr}\right) + \beta\left(\frac{u}{r}\right) \text{ and } t = \alpha_1\left(\frac{du}{dr}\right) + \beta_1\left(\frac{u}{r}\right)$$

where p and t are (as has been stated) the intensities of a pair of stresses at right angles to each other at any point of the ring $E_1 F_1 e_1 f_1$.

Now if the properties of the metal are independent of direction, *i. e.*, if the elasticity is the same in all directions; we ought, by interchanging coördinates and hence by interchanging $\frac{du}{dr}$ and $\frac{u}{r}$ to deduce either of the above equations from the other: hence we must have $p = \alpha_1\left(\frac{u}{r}\right) + \beta_1\left(\frac{du}{dr}\right)$. This can only be when

$\alpha_1 = \beta$ and $\beta_1 = \alpha$; hence we have:

$$p = \alpha\left(\frac{du}{dr}\right) + \beta\left(\frac{u}{r}\right) \text{ and } t = \beta\left(\frac{du}{dr}\right) + \alpha\left(\frac{u}{r}\right);$$

where α and β, in the case of a homogeneous body whose elasticity is constant in all directions, are constant quantities depending on the properties of the material.

From all the preceding we have the following three equations:

$$\frac{dp}{dr} + \frac{p-t}{r} = o \qquad (1)$$

$$p = \alpha\frac{du}{dr} + \beta\frac{u}{r} \qquad (2)$$

$$t = \beta\frac{du}{dr} + \alpha\left(\frac{u}{r}\right) \qquad (3)$$

Differentiate (2) and we have $\frac{dp}{dr} = \alpha\frac{d^2u}{dr^2} + \frac{\beta}{r}\frac{du}{dr} - \frac{\beta u}{r^2}$.

Subtract (3) from (2) and we have:

$$p - t = \alpha\left(\frac{du}{dr} - \frac{u}{r}\right) - \beta\left(\frac{du}{dr} - \frac{u}{r}\right) = \alpha - \beta\left(\frac{du}{dr} - \frac{u}{r}\right).$$

Substitute these values of $\frac{dp}{dr}$ and $p - t$ in (1) and we have:

$$\alpha\frac{d^2u}{dr^2} + \frac{\beta}{r}\frac{du}{dr} - \frac{\beta u}{r^2} + \frac{\alpha}{r}\frac{du}{dr} - \frac{\alpha u}{r^2} - \frac{\beta}{r}\frac{du}{dr} + \frac{\beta u}{r^2} = o.$$

Cancelling $\frac{\beta}{r}\frac{d\,u}{d\,r}$ and $-\frac{\beta\,u}{r^2}$ with $-\frac{\beta}{r}\frac{d\,u}{d\,r}$ and $\frac{\beta\,u}{r^2}$ respectively, and dividing by α we obtain:

$$\frac{d^2 u}{d\,r^2} + \frac{1}{r}\frac{d\,u}{d\,r} - \frac{u}{r^2} = o.$$

By transposition we have: $\frac{d^2 u}{d\,r^2} = -\left(\frac{1}{r}\frac{d\,u}{d\,r} - \frac{u}{r^2}\right);$

but $\frac{1}{r}\frac{d\,u}{d\,r} - \frac{u}{r^2}$ is the differential coefficient of $\frac{u}{r}$ with regard to r, or to $\frac{d\left(\frac{u}{r}\right)}{d\,r}$; hence $\frac{d^2\,u}{d\,r^2} = -\frac{d\left(\frac{u}{r}\right)}{d\,r}$

$\therefore \quad \int\frac{d^2 u}{d\,r^2}\,d\,r = -\int\frac{d\left(\frac{u}{r}\right)}{d\,r}\,d\,r$; or performing the integration we have $\frac{d\,u}{d\,r} = -\frac{u}{r} + 2\,a$ ($2\,a$ being a constant whose value is not yet determined).

Multiplying by r and transposing we obtain:

$$r\frac{d\,u}{d\,r} + u = 2\,a\,r;$$

but $r\,\frac{d\,u}{d\,r} + u$ is the differential coefficient of $r\,u$ with regard to r or to $\frac{d\,(r\,u)}{d\,r}$; hence we have:

$\frac{d\,(r\,u)}{d\,r} = 2\,a\,r$; multiplying by $d\,r$ and integrating

$\int\frac{d\,(r\,u)}{d\,r}\,d\,r = 2\,a\int r\;d\,r$, or $r\,u = a\,r^2 + b$ (b being another undetermined constant). $\therefore\; u = a\,r + \frac{b}{r}$,

and from this equation we obtain directly the two strains, *viz.*:

$$\frac{d\,u}{d\,r} = a - \frac{b}{r^2} \text{ and } \frac{u}{r} = a + \frac{b}{r^2}.$$

Substituting these in the values of p and t we have:

$$p = \alpha\left(a - \frac{b}{r^2}\right) + \beta\left(a + \frac{b}{r^2}\right) = a\,(\alpha + \beta) - \frac{b}{r^2}\,(\alpha - \beta)$$

$$t = \alpha\left(a + \frac{b}{r^2}\right) + \beta\left(a - \frac{b}{r^2}\right) = a\,(\alpha + \beta) + \frac{b}{r^2}\,(\alpha - \beta).$$

Next we proceed to determine the values of a and b, and to do this we must observe that when $r = R$, or when the thin ring is taken as the ring whose radius is OA, we have $p = -P$ (the minus sign being used because it is a compressive force), and when $r = R_1$, we have $p = -P_1$.

Making these substitutions we obtain:

$$a(\alpha+\beta) - \frac{b}{R^2}(\alpha-\beta) = -P; \quad a(\alpha+\beta) - \frac{b}{R_1^2}(\alpha-\beta) = -P_1;$$

two equations of the first degree from which to determine a and b; any method of elimination will give us:

$$a = \frac{1}{\alpha+\beta}\left(\frac{PR^2 - P_1R_1^2}{R_1^2 - R^2}\right), \text{ and } b = \frac{1}{\alpha-\beta}\left(\frac{(P-P_1)R^2R_1^2}{R_1^2 - R^2}\right).$$

Substituting these values of a and b in the last value of t we have:

$$t = \frac{PR^2 - P_1R_1^2}{R_1^2 - R^2} + \frac{1}{r^2}\,\frac{(P-P_1)R^2R_1^2}{R_1^2 - R^2},$$

which is the intensity of the hoop tension in the ring $E_1 F_1 e_1 f_1$. The greatest value of t, or the greatest hoop tension evidently occurs in the inside ring, or when $r = R$, when the maximum value of t becomes:

$$= \frac{PR^2 - P_1R_1^2}{R_1^2 - R^2} + \frac{(P-P_1)R_1^2}{R_1^2 - R^2} = \frac{PR^2 - P_1R_1^2 + PR_1^2 - P_1R_1^2}{R_1^2 - R^2},$$

and the greatest intensity of hoop tension:

$$= \frac{P(R^2 + R_1^2) - 2P_1R_1^2}{R_1^2 - R^2}.$$

If the intensity of the working strength of the material be k, we must therefore have, in order to ensure safety:

$$k = \frac{P(R^2 + R_1^2) - 2P_1R_1^2}{R_1^2 - R^2};$$

or, clearing fractions, we have:

$$kR_1^2 - kR^2 = PR^2 + PR_1^2 - 2P_1R_1^2;$$

transposing and factoring:

$$R_1^2(k - P + 2P_1) = R^2(k + P);$$

dividing by $k - P + 2P_1$ we have:

$$R_1^2 = \frac{k+P}{k - P + 2P_1}R^2.$$

Extracting the square root $R_1 = R\sqrt{\dfrac{k+P}{k - P + 2P_1}}$, which determines the external radius when the internal radius, the outside and inside pressures, and the working strength of the material are known. In the more common case when there is no external pressure, as in the

case of the hydrostatic press, when the pressure of the external air is left out of account, P_1 is to be made equal to zero, and the above formulæ become:

Intensity of maximum hoop tension:

$$= P \frac{(R^2 + R_1^2)}{R_1^2 - R^2}, \text{ and } R_1 = R \sqrt{\frac{k + P}{k - P}}.$$

Hence, if in the case of a thick hollow cylinder, we have $P =$ intensity of internal normal pressure; $P_1 =$ intensity of external normal pressure; $R =$ inside radius of cylinder; $R_1 =$ outside radius of cylinder, and k intensity of working strength of the material; or, which is the same thing, $=$ intensity of maximum hoop tension consistent with safety, we shall have:

1st, Suppose P, P_1, k and R are known, and R_1 required:

$$R_1 = R \sqrt{\frac{k + P}{k - P + 2 P_1}} \text{ when there is an external pressure,}$$

$$R_1 = R \sqrt{\frac{k + P}{k - P}} \text{ when there is no external pressure.}$$

2d, Suppose with the same data that the thickness of the walls be required, we shall have:

Thickness when there is an external pressure:

$$= R_1 - R = R \left\{ \sqrt{\frac{k + P}{k - P + 2 P_1}} - 1 \right\}$$

Thickness when there is no external pressure:

$$= R_1 - R = R \left\{ \sqrt{\frac{k + P}{k - P}} - 1 \right\}$$

3d, Suppose R, R_1 and k to be known, and it be required to determine the greatest internal normal pressure that can be safely used, and we shall have:

$$\text{Intensity of greatest pressure} = P = k \frac{R_1^2 - R^2}{R_1^2 + R^2}.$$

4th, If R, R_1, P and P_1 be given, and it be required to determine the actual intensity of the greatest hoop tension, we shall have:

Intensity of greatest hoop tension, when there is an external pressure:

$$= k = \frac{P\,(R_1^2 + R^2) - 2\,P_1\,R_1^2}{R_1^2 - R^2},$$

Intensity of greatest hoop tension when there is no external pressure:

$$= k = P \frac{R_1^2 + R^2}{R_1^2 - R_2}.$$

GAS WORKS ENGINEERING.

By Robert Briggs, C. E.

[Continued from Vol. cii, page 272.]

"There were two sets of purifiers, twenty feet by twenty-four feet on the floor, by five feet deep, having two-feet seals for the covers; with a thirty-inch main pipe and twenty-four inch branch to and from each set of purifiers. The purifiers had a single layer screen, each with a bed of oxide preparation, twenty inches in depth. The preparation was said to be oxide of iron, iron-borings, charcoal, and I think lime. The beds of oxide preparation in the three purifiers gave but two inches of water column as the resistance pressure, as exhibited to me; and the time of service of a bed, before it was fouled (for the full production of the works—about twenty-five thousand cubic feet per day, per set of purifiers), was said to be three to four days, or about eight millions cubic feet of gas would pass a set of purifiers before a bed would require revivification.

"The reviving of the preparation was done in a yard and in an old deserted and open retort building adjacent to the purifying-house. The material was heaped as usual, for other oxide, one day, and gradually spread, to avoid the excessive heat which attends a more complete exposure to the air.

"The odors attending this revivification were much less obvious than that accompanying the handling of foul lime at Philadelphia, although not so strong with ammonia as I have generally found at pure oxide heaps. They were using an '*enricher*' of ten per cent. of cannel coal to bring the gas up to sixteen candles quality, indicating a somewhat imperfect removal of carbonic acid.

"It should be stated here, that good Westmoreland, or other American gas-coal, will yield, with careful charging of the coal into the retorts, quite four and one-half cubic feet of gas (of sixteen candles quality) to the pound of coal; and if any coal, by weathering or otherwise, fails to give this quantity for the yield, it is customary to put in as a part of the charge, a portion of coal (like cannel) which will of itself alone be capable of giving gas of twenty-four to thirty candles quality; and this act is called '*enriching.*'

"I next visited the Mutual Gas Works, Eleventh street and Avenue B, on the East river. At these works they have in all ninety-five benches for coal-gas, with six retorts to each bench, and nine benches for naphtha-gas, also with six retorts to each bench. The retorts were 13″ by 24″ by 9′. The largest quantity of gas possible was made from the coal retorts—or a little over five cubic feet per pound on the average, for the year's work; and this gas was then *enriched* by naphtha-gas of forty candles quality, to bring the whole gas delivered from the holder up to twenty candle quality.

"The usual work of the retort-house here, presented no subject for comment. The washer and condenser rooms might have been a parlor for all the odor allowed to escape; the washing was done partly or wholly with ammonia water. There were two sets of purifiers, each twenty feet by twenty-four feet on the floor, by three feet deep, with twenty inch seals. In these purifiers there is but one layer of an oxide preparation, twenty-eight inches in depth.

"The preparation was a secret one, perhaps patented, and the gas was perfecty satisfactory for sulphur purification, the same prepared material had been in use over a year, and the purifiers required changing once a week or so.

"An inspection of the revivifying floor was much more satisfactory to the nostrils than that previously made at the New York Gas Works, but a slight gas-effluvia was present—that is, such a smell as attends gas-lime as distinguished from the ammonia vapors of pure oxide of iron revivification. I came away from these works without a trace of odor in my hair or clothes; while the result of two visits, of similar duration, at the Market street works, was, that at both times the odor brought away was persistent and obnoxious to an excessive degree, remaining attached to clothing for two or three days afterwards.

"It is proper to say, that, as naphtha-gas is used for enriching, the gas of the Mutual Company is, in some measure, independent of the presence of non-luminants, since a little more of the naphtha-gas will overcome this cause of imperfection; and, also, that the naphtha-gas is an experiment of yet undetermined result. Former attempts to supply mixed gases and '*carburetted gas*' have terminated unfortunately, from troubles of distribution in the mains or services, or in burning, or by cost of production, or in some unhappy way, to most parties interested.

"These examples will serve to show that some processes of oxide-of-iron purification are practiced in the United States, and that they are comparatively devoid of objectionable smells. The managers of the two works here instanced, state that the cost of oxide-of-iron purification is much less than half that of lime purification.

"In the quotations from my notes upon the use of oxide of iron for purification, allusion is only made to the avoidance of odor, and no definite description is given of the process of revivification and its products. To supply that want of completiveness of the notes, I will state, the material is removed from the discarded purifiers and wheeled in barrows to a covered floor, where it is first piled in a heap three to five feet in depth. So soon as it is exposed to the air, it commences to heat, and it is therefore banked at first, in order to give a surface exposure only. The heating is attended with a copious effusion of ammonia gas, with a trace of naphthaline odor, and a little steam from evaporation of moisture from the oxide, which is usually damp from condensation from the gas. The next day after making the heap, it will be sufficiently cooled to be turned over into rows, and on the following day to be spread in a thin layer. If the floor is large enough to allow this spreading to form a layer of two to three inches thickness, no further turning over is requisite; but the oxide must be raked once or twice on the third day, and if the layer be thin and the oxide manipulated at the proper time, it will have been *revivified* at the end of the third day. The effusion of ammonia occurs only when the oxide is turned over or disturbed, and is of short duration (a few minutes only) after the turning or spreading ceases. The principal chemical changes are substantially inodorous.

"Some attempts have been made to revivify the oxide in the purifiers without moving it, by admission of air through suitable connections, but they have resulted in failure (I am told), in consequence of the great heat evolved when the pressure of air is sufficient to pass it through the bed of foul oxide.

"It must be remarked, that the resistance of flow of gas through the purifiers is much greater for the general system of oxide purification than for lime purification; but it has been shown that the requisite apparatus for impelling the gas already exists at the Market Street works, and the question of additional power needed to effect the purpose is really insignificant, as the movement of all the gas possible to be made at these works at any time, under

eighteen inches of water-column pressure, will not exceed the performance of a ten horse-power engine.

"The process of oxide-of-iron purification results in great saving of expense to the gas-maker. At the New York Gas Works it was asserted that the entire cost of purification did not exceed five-eighths of a cent per thousand cubic feet of gas made. It is unquestionable that the use of the oxide process would result in great profit to the Gas Trust from saving of labor and of crude material, and I believe would be highly advantageous to the consumers, in the improvement of the quality of gas made, the value of which would far more than recompense the cost of introducing the process.

"There is yet another way to avoid the nuisance proceeding from dry-lime purification, which is exhibited at the works of the Manhattan Gas Company, visited by me on the 16th and 17th of March (inst.) The North River Station of the works of the Manhattan Gas Company of New York, is located on the blocks of ground west of Tenth Avenue, on West Eighteenth and Seventeenth Streets and adjacent streets. Omitting any general description of the works, only to say that the condensing and washing house was devoid of the least possible odor, I will proceed to a particular account of the system of ventilation of the foul-lime resulting from dry-lime purification, there in successful operation. At these works they have (for the one thousand and thirty-two retorts in the benches, eight hundred and forty—highest number in use at one time) three sets of purifiers, seventeen feet by twenty-two feet on the floor, by three and one-half feet deep, with seven layers of lime in each, and the usual connecting pipes of inlet and outlet.

"Besides these usual pipe connections for gas, they have likewise connected to the bottom of each purifier, a sixteen-inch pipe with a suitable stop-valve; these pipes join into a twenty-four inch main pipe, and the latter connects to an exhauster, in this instance a species of screw-fan, five feet in diameter. From the exhauster, a twenty-four inch pipe leads to a jet-washer, which corresponds in construction to that before described at Market Street works, only it is but one-fourth the length (that is, ten feet in lieu of forty feet on the floor), the height and width being about the same as the Philadelphia washers. All this part of the apparatus is in close proximity to the purifying-house. From the washer, the pipe continues to a drain-pipe three feet high by two feet wide (egg shape), which leads

under the roadway of West Seventeenth Street, nearly one thousand feet, to a deodorizing building. This deodorizing building has two closed deodorizing-*rooms*, with only a doorway for entrance, and on the floor of each room is a *brick* deodorizer-box, without cover. These boxes are thirty feet long by sixteen feet wide by three and one-half feet deep, and have seven layers, of similar construction to those used in usual dry-lime purifiers. Branches from the main drain-pipe, controlled by valves, open into the bottoms of the brick purifiers; and openings, also controlled by valves, from the upper part of the rooms, lead to a chimney seventy feet high. The screens are covered with ventilated *spent-lime*, about one-tenth of all the lime being used at these secondary purifiers. The purpose of this apparatus is the *ventilation* of the foul lime in the purifiers, and it is effectual in this way:—

"When a purifier is ready to discharge, and is shut off as usual from the gas works by the centre valve, the cover is lifted from the seat and suspended about one inch above the box. The valve of the ventilating pipe is opened and the ventilating exhauster started. Air is sucked into the purifier from the top, and the foul lime is ventilated for one and a half hours, at the end of which time it will be found decomposed and deodorized to such an extent that it can be properly denominated spent-lime; at all events, it is devoid of any marked unpleasant odor, and will have ceased to possess the power of originating them. In this condition, spent-lime is really available for immediate use for agricultural purposes. During the operation, the lime in the box heats to, perhaps, 140°, and from an approximate estimate, founded on the speed of the fan (six hundred revolutions per minute), about 300,000 to 400,000 cubic feet of air will have been passed through the layers of lime.

"The wash water is brownish yellow, and not offensive; it is run off into the sewer.

"Very unexpectedly, the long drain-pipe main was found to have acted as a condenser of naphthaline, whose presence in great quantity, in foul lime, has not been before noticed. The pipe was coated with naphthaline to the extent of *five or six inches* after a year's use, and it was removed by introducing a jet of steam and blowing it through by means of the exhauster. [It would seem that naphthaline was soluble in steam or vapor of water, while it is nearly insoluble in water.]

"Having reached the secondary purifying-house, the foul air is passed through one of the *rooms* and discharged through the chimney into the open air. The deodorizing material in this case was stated to be spent-lime from the gas purifiers. It was found that pure lime had no effect on the foul air, and at the suggestion of Mr. Carl H. Schultz, chemist, New York, the *spent-lime* was employed with great success. The lime on the deodorizing screens is revived in part, by forcing *fresh* air throught it for an hour, after the operation of ventilating a gas purifier has ceased. The lime is customarily changed in the deodorizing house, for every purifier changed in the purifying house. This operation is highly satisfactory to the Manhattan Company, and answers to meet all the requirements of the New York Board of Health, which has forbidden the use of dry-lime purification at the gas works of that city.

"[§§ *Five.*] At the Market Street works, beside the manufacture of gas, there are two perpetual lime-kilns for the making of oyster-shell lime for use in the purifiers. This branch of the business is not carried on, to my present recollection, by any other gas works in this or in other countries.

"The plant is a very simple one. A stone structure, about thirty feet long by sixteen feet broad and twenty-five to thirty feet high, contains two kilns or 'stacks,' internally cylinders of eight feet or so in diameter, with the lower part reduced to perhaps three feet; square openings from one side permit access to the bottoms or hearths of the stacks. The base of the stacks is surrounded by temporary buildings or sheds. These stacks are situated between the purifying house and the Schuylkill river, and are about one hundred and fifty, or two hundred feet north of Chestnut Street Bridge; between them and the bridge, the space of wharf is utilized, first by the foul-lime dump, and next, by a pile of generally twenty thousand to forty thousand bushels of oyster-shells (or more).

"The operation of making lime in these stacks, is to charge at the top a quantity of oyster-shells, mixed with one-fourth the quantity of coke breize and fine coke dust; and at certain regular intervals some bars of iron are driven in across the tops of the openings to the hearth, and the burned oyster-shells under the bars, now converted to lime, are *drawn* out; when, removing the bars, the charge falls from bottom to top; and after the stack has once been lighted, the process of burning will go on continuously with regularity.

"At first there arises and escapes from these kilns the steam from the moisture of the oyster-shells, laden with the odors of cooked oysters, mingled with those proceeding from decayed remains; and after this, and accompanying it, escapes a volume of nearly pure carbonic acid; together with a little chlorine vapor or gas, and some small quantity of other gases. This carbonic acid proceeds from the carbonate of lime of which the oyster-shells are mainly composed, and from the combustion of the coke, which disappears altogether during the process; and as this gas, at the temperature of leaving the kiln, where the upper layer of oyster-shells and the moisture will have nearly taken up all the heat of burning the coke, which occurs at or below the middle of the stack, has about the same density as the external air, it follows that, although it may diffuse rapidly, yet it does not dissipate by ascension. I am informed by competent authority that the height of the approach of the Chestnut Street Bridge, in front of the heap of oyster-shells at the gas works, is thirty-one feet six inches above top of ground. Consequently, as the tops of these kilns are nearly at the same level as Chestnut Street Bridge (about two hundred feet distant to the southward), and of Market Street Bridge (about three hundred feet distant to the northward), any current of air up or down the river will sweep these gases and odors directly across them.

"The oyster-shell heap, near Chestnut Street Bridge, emits disagreeable odors, and, speaking of it in the mildest terms, can be generally denominated as offensive to the public. I only state the existence of the heap to complete my narration of the arrangement and occupation of the grounds of the Market Street Station of the Philadelphia Gas Works.

III. It cannot be said by any person practically acquainted with the manufacture and supply of gas, and competent to advise on the location of gas houses, that the Market Street works are judiciously situated as regards the main thoroughfares and streets of the city, although the place may give, at this time, great advantages for distribution. The barn-yard and the pig-pen are necessary adjuncts to the farm dwelling, and the farmer is happy in their contemplation; but if the county lays out a road behind the farmer's house, when his barn is outgrown he will be likely to build a new one in another place.

"It must be regarded as a grave error that the works were not removed, in place of having been reconstructed on a larger scale, a few years since.

"The holders could have been and should have been preserved, and possibly additional ones erected, but after *the entrance* of the city was established by the erection of the passenger station of the Pennsylvania Railroad, and Market Street became the important avenue, some reasonable expenditure should have been incurred to have removed the operation of making gas to some other part of the city. And this could have been done by the construction of a single five foot or six foot wrought-iron pipe main, at no enormous outlay, considering the importance of the object.

"The Beckton Gas Works, of the Chartered Gas Company of London, which are situated nearly eight miles below the centre of distribution, and where there are two thousand one hundred and sixty double-ended retorts (equivalent to four thousand three hundred and twenty retorts of the Market Street size), can be taken as an example of the recognition of the comity of the public as weighed against the right to carry on objectionable manufactures in the midst of a city, no matter how necessary to the city itself such a manufacture may be. Any person will tolerate and endure in his shop, laboratory, manufactory or avocation, odors or dust more or less unhealthy and disagreeable, but no one will desire these inconveniences at his home.

"IV. The time requisite to make the changes necessary to avoid the nuisances now proceeding from the Market street works can be stated as follows, taking up the various sources of complaint in order:—

"*First.*—The construction of a house and smoke-tower for quenching the coke can be effected the present season; certainly before autumn sets in.—The economy of quenching and handling coke by shutes would probably defray the interest of cost of house, &c.

"*Second.*—The disuse of lime purification and the substitution of oxide of iron, as used at the works of the New York Gas Company or those of the New York Mutual, could be done at once, upon procurement of oxide or 'prepared material.' I think that this change could readily be effected within one week. The introduction of the English process of purification could be done by temporary pipe connections, so as to give the use of two sets of the purifiers within

two weeks' time; and the construction of necessary additional purifiers for use of the three sets could be readily effected this present season.

"The plea of delay in getting perforated screens at the Metropolitan Works (New York), stated to have been made by the officers of that company, as appears in the affidavit of Professor C. F. Chandler, was purely a dilatory one. I do not remember ever to have seen perforated screens used with oxide of iron, and slat screens, such as are used at the Philadelphia Gas Works, are those generally if not universally employed.

"The construction of temporary sheds to cover the revivifying floor would take but a few days, and permanent structures of suitable character for the locality could easily be built this season. The profit to the gas company arising from the substitution of oxide of iron purification would probably be $4000 to $5000 per year at the Market street works alone.

"Any desired amount of oxide of iron can be procured at a week's notice; but two weeks' delay might arise in crushing or preparing it for the first start.

"*Third.*—The introduction of the system for deodorizing foul lime now used in the Manhattan Company's Works in New York could be effected in six weeks' time, if any urgency existed; or in twelve weeks' time, at leisure.

"*Fourth.*—The disuse of the lime-kilns, by the substitution of *better* lime for purification, could be effected at six days' notice, which would be the time requisite to commence the railroad deliveries of the quantities needed. The marble from which nearly pure lime can be made can be found in abundance within *fifty* miles of Philadelphia, where kilns now exist ready for burning it. A bushel of marble-lime is equal in weight and efficiency to two and one-fourth bushels of oyster-shell lime.

"*Fifth.*—The removal of the kilns to Point Breeze or elsewhere could be effected, if any urgency existed, in six weeks; but at leisure perhaps thirteen or sixteen weeks would be required."

STREET AND TRAM LOCOMOTIVES.

From *The Practical Magazine*, London, Sept., 1876.

In our number for June (page 176 of the present volume) we inserted, from the JOURNAL OF THE FRANKLIN INSTITUTE, a few paragraphs concerning the use of steam carriages on street railways and common roads. At page 188 we gave a description and engraving of Messrs. Merryweather's steam tram-carriage, lately commenced working on the Paris tramways. It occurs to us that it may be useful to present here a few connecting links of history, so as to prepare the general reader for a due comprehension of other novelties which are likely to make their appearance ere long. Railways, as we all know, have solved the problem of steam-power *vs.* horse-power, so far as regards the traction of heavy loads at high speed. It remains still to be ascertained whether this substitution ever can or will be so complete in regard to what may be called "omnibus traffic," distinguished by lighter loads, lower speed, and more frequent stoppages. It becomes, on this account, interesting to glance at the inventions which, from time to time, have been brought forward, partly for steam-traction on tramways, but more generally for use on common roads.

If we mention Sir Isaac Newton's name in connection with this subject, it is only in relation to a speculation which he made no attempt to put to a practical test. He suggested a globular vessel, placed on four small wheels, with a jet-pipe on one side and a driver's seat on the other. Steam, generated in the globe by a suitable fire, would issue from the tube and drive the little four-wheeler onward by reaction, on the principle of the rocket. Dr. Robinson, nearly a century later, communicated to James Watt an idea for the propulsion of a carriage along common roads by steam. A cask of iron-bound staves for a boiler; an iron furnace or fire-box, fed from above, immersed in the water in the cask; steam from the heated water moving a piston in a cylinder, and the piston moving a small wheel-carriage on which the cask, &c., were placed,—such was the idea; but Watt carried it no further than the sketching of a few drawings.

Of those who really advanced to the stage of an actual carriage, or at least a working model, one of the first was Cugnot, who made

a rude model, still preserved in one of the public museums of Paris, and then a carriage, which proved to be too energetic at its work, for it dashed through a brick wall and brought disfavor to its inventor. William Murdoch, about 1790, ran a steam carriage on the highway near Redruth, but the chief fact now known concerning it, is, that the Cornish miners rushed away in affright from "the fiery little monster running along the road without horses." William Symington, whose name is as favorably associated with the history of steam navigation as Murdoch's with that of gas-lighting, exhibited at Edinburgh a model of a steam carriage, the merits of which he was unable to test by reason of the wretched state of the roads. Oliver Evans, of Pennsylvania, proposed to the legislature of that state a scheme for steam traction on common roads; his plan met with no response. He was greatly laughed at for prophesying that the day would come when such carriages would attain a speed of fifteen miles an hour. Who was nearer the truth, the derider or the derided?

Early in the present century we find Trevithick and Vivian completing and running their steam carriage on the very spot where the Euston station now stands—not a bad association of ideas, it will be admitted. From the description published, it seems to have been a tolerably light and compact piece of mechanism. A carriage rested on four wheels, of which the front pair guided or steered, while the hinder part supported the greater part of the weight; a boiler and a horizontal cylinder were placed at the back of the hind axle, while rods, tooth-wheels, cranks, &c., connected the piston of the cylinder with the wheels of the carriage.

Nobody took up these schemes in earnest—war and political troubles occupied men's thoughts in other than peaceful pursuits. But a new spurt took place just about half a century ago. Mr. Griffiths employed Bramah to work out an idea of his, and to make improvements in practical details. Little is now known of the steam carriage which resulted from this partnership in ingenuity, except that there were two cylinders with pistons, a tubular boiler, and vertical springs to deaden the concussion. Another inventor, David Gordon, had firmly persuaded himself that no locomotive carriage, or steam engine on wheels, can travel up an incline. He therefore devised a strange monster, with six jointed levers to act like six legs, with bending movements to imitate those of knees and insteps, the legs alternately stepping and dangling! Another mode of overcom-

ing the supposed difficulty was by putting a steam engine inside a large iron drum, making the engine roll the drum as a squirrel rolls his cage, and a carriage to roll on after the drum.

When it was proved that a locomotive *can* travel up hill, if not steep, inventors took courage, and novelties appeared in rapid succession. Goldsworthy Gurney built a steam carriage which Sir Charles Dance "tooled" (as coaching men would call it) between Gloucester and Cheltenham. It ran to and fro four times a day, doing the distance of nine miles in about an hour. All kinds of obstacles were thrown in his way. Innkeepers, hostlers, horse-dealers, coachmakers, road trustees, interposed impediments wherever possible. Gurney and Dance were beaten; but nevertheless they obtained a favorable report from a committee of the House of Commons. The committee fairly judging the evidence brought before them, reported that the steam carriage could maintain an average speed of ten miles an hour; that it would carry twelve or fourteen passengers; that the total weight of carriage, machinery, fuel, water, passengers, driver, and attendant, might be under three tons; that the carriage, with such a load, would ascend and descend ordinary roads with facility; and that the broad wheels were less likely to cut up the roads than the narrow wheels and horses' feet of ordinary road vehicles. Whether the system would eventually be cheaper than horse-traction could not be determined on so short an experience.

Captain Ogle was another experimenter in the same line. He made a great sensation by running a new steam carriage from Oxford to Birmingham, ten miles an hour in the towns, and twelve miles in the more open country. His contrivance was a kind of mail coach for six inside passengers and eight outside, the motive power being placed in the rear of the passenger compartment. Rivals appeared in this district and in that, but all went into oblivion after a brief period of excitement. Mr. Hancock's "infant" steam coach plied for a time to and fro between London and Stratford. A steam coach under the command of Colonel Macerone, in like manner had its little day. Mr. Scott Russell (perhaps the only distinguished living representative of that group of inventors) constructed a steam carriage which plied for a time between Glasgow and Paisley. Burstall (a name that might be regarded as rather ominous in connection with such subjects), with his partner Hill, Summers and Ogle, Dance and Field, James, Heaton, Church, Squire, Hills, Sir James Anderson—all are

to be included among the inventors which turned their attention to these matters at various periods from half a century to a quarter of a century ago. Why they all failed we need not wait to say. Some of the engines were too heavy; some had difficulty in maintaining their water-feed; some did not steer readily nor stop with sufficient promptness; some frightened the horses with their noise; while others were placed beyond the reach of profit by inordinate tolls imposed by turnpike trusts.

There is still no paucity of invention of steam coaches, if the smallest encouragement be offered them. The Earl of Caithness created quite a lively sensation in Scotland a few years ago, by performing a journey which certainly was unequaled of its kind. A very ingenious steam carriage was invented by Mr. Rickett. It was a kind of hooded chaise, with a small steam engine behind it, occupying about as much space altogether as a horse and chaise; the chaise had a seat for three persons, while the engine was attended to by a fourth person, stationed in the rear. A supply of coal for fifty miles and of water for fifteen could be carried; when thus supplied, the whole affair, with four persons, weighed about a ton and a half. On a given day the Earl started off, occupying the position of driver, with the Countess of Caithness by his side, a clergyman at the other end of the same seat, and Mr. Rickett acting as stoker. On they went, starting from Inverness, and taking the mail coach road through Beauly to Dingwall, Golspie, Durabin, Helmsdale, the Ord of Caithness, Berriedale, Wick, to Barrogell Castle—a ride of 150 miles. The ascent and descent of the Ord of Caithness, one of the stiffest bits in Britain, showed that the wheels of the little vehicle took a good hold of the road.

Without touching further on these steam coaches, we may say a few words concerning the use of traction engines for dragging heavy weights over bad roads, or rough ground without any road at all. The success of these is beyond all question. One of the first was Taylor's "Steam Elephant," employed at Messrs. Laird's to drag marine boilers and other heavy masses of iron from the works to the harbor at Birkenhead. It was afterwards used in other places, usually to support a powerful crane, which lifted up heavy weights, wheeled them along, and deposited them at another spot. The "Steam Bull" was a rival to the "Steam Elephant," and used in a similar way. Bray's traction engine, at one of its early trials, carried or

drew a boiler of 30 tons, an armor-plate of 17 tons, and two other plates, all at once. One of these engines, sent out to the South American mines, rendered great service at a spot where there were literally no roads, lowering ore down from the mine to the harbor and dragging up stores. Avelong and Porter's traction engine is another of these excellent contrivances, adapted for various kinds of farm and quarry work, and as a feeder to railways along roads where the traffic would be too small to pay for a rail. Thomson's engine is also remarkable, noticeable for the thick bands of india-rubber which form the tires of the wheels, and enable them to get over rough ground without much jolting.

As to steam vehicles on the common roadways of streets in our busy towns, we are almost as much without them now as ever. The chief exception is the road-roller, used for crushing and smoothing the surface of newly macadamized carriage-ways. The legislature has hitherto discouraged rather than encouraged the appearance of "Puffing Billy" in our streets. In 1862 an Act was passed to regulate the employment of locomotives in the streets, under the belief that they were at that time coming into use. The weight and the gauge were to be limited; they were to consume their own smoke; they were to carry lights at night; they were to carry a guard as well as a driver and a stoker; and they were not to exceed a speed of five miles an hour in towns. Another statute, in 1866, made matters still more stringent, by enacting that the speed should be lessened to two miles an hour in town streets, with a man running on ahead on foot, waving a red flag, to warn persons to keep out of the way; and noisy steam whistles were interdicted. Whether commercial traffic could live under such iron rules, the future may perhaps show; steam omnibuses for passengers would obviously find no trade at two to four miles an hour.

Tramways, as we all know, had a precarious infancy in this country, but they have surmounted their preliminary troubles, and have become fairly remunerative undertakings. The high price of hay and oats gradually led the companies to inquire whether the tram cars could be safely and profitably drawn by steam-power. Foreign countries have preceded us in this application. Kohl's steam cars (an illustrated description of which appears in our last number) have, for some time, been working successfully in the streets of Copenhagen; Harding's in Paris, and others elsewhere. An arrange-

ment by Messrs. Merryweather was tried for some time in Westminster, but circumstances were unfavorable to its success. A greatly improved construction by the same makers is described on page 188, illustrated by an engraving; this has been brought into use on some of the Paris tramways. Mr. Grantham invented a steam car, which was tried experimentally at West Brompton, and is, now, we believe, working on a short bit of country road; he planned many improvements in it, but did not live to finish them. Mr. Hughes, of Loughborough, who has built many small locomotives for use on mineral railways, has recently adapted them for a tramway at Leicester. His tram locomotive has a pair of 6-inch cylinders, 12-inch stroke; as it is fed only at the beginning of each journey, there is no need for a fuel-box. Coke is used to prevent smoke; the chimney does not protrude above the roof, and the working mechanism is boxed off to avoid frightening horses. The weight of engine and car, with coke and water for six miles, is about five tons.

Within the last few weeks a trial has taken place on the Hoylake and Birkenhead Tramway, of a tram locomotive by Woods, intended for Vienna. The engine and car form parts of the same structure. Shand and Mason's patent inclined water-tube boilers are employed. The cylinders, 6-inch diameter and 9-inch stroke, are placed under the platform, and are coupled direct to a pair of steel driving wheels, 2 feet diameter. Each end of the car has its own brake, steering gear, and passenger entrance. The boiler is at one end, while the other is supported on a bogie-truck. One man can manage the driving, stopping, stoking, &c. The car will carry twenty passengers. The water tanks are placed under the passengers' seats, and the boiler can be supplied either by an injector or by a donkey engine.

Enough; the future must show whether steam or horse-power is to rule the great systems of tramways. Hitherto, those tram locomotives which have failed, have done so because the smoke and heat have annoyed the passengers, or because the noise has frightened the horses of passing vehicles, or because the sunk capital, wear and tear, and working expenses have exceeded the total outlay entailed by horse traction. This last, we suspect, will be the *experimentum crucis*, the real test that will settle the whole question. Say that a large car, carrying forty passengers inside and out, can be drawn along at a fair speed by two horses—what will be the cost of these horses, the renewal, the stable and veterinary expenses, the hay and

oats? And what the cost of steam engine, repairs, coke, water, &c.? These are sums in arithmetic which no preconceived theory oan solve.

In this connection we now learn that a new steam hand car has recently been designed and constructed by Mr. Jay Noble, master mechanic for M. M. Buck and Co., of St. Louis, Mo., which is excellently adapted for the use of division superintendents, road masters, and others whose duty requires them to make frequent inspection of railway lines. The machine resembles an ordinary hand car, except that the propelling power is steam and not muscle. The floor is about 10 inches from the ground, and is beneath instead of above the axles. The boiler, which is about 3½ feet in height, with a diameter of 18 inches, is placed in the centre of the car, while the cylinder, which is horizontal, is at the right hand side and near the floor. The cylinder is 3½ by 6 inches, and the boiler is intended to carry a pressure of 140 lbs. of steam. The body of the vehicle rests on rubber springs, and rides very easily without lateral motion. Seats are arranged in front and rear, of sufficient size to accommodate six persons. The water tank occupies a space under the back seat and holds about a barrel of water, which is sufficient to run the car forty miles. On the left of the boiler the coal pan is arranged in a space about 2 feet wide, and carries all the fuel necessary for a day's run.

On a recent trial trip, the run from St. Louis to Carondelet, a distance of seven miles, was made in fifteen minutes. The inventor states that under ordinary circumstances the cost of fuel will not exceed three shillings per day. The general arrangement is excellent and reflects much credit on the designer.

Errata.—In consequence of absence of the Editor at the time of making up the editorial pages of October Journal, a few typographical errors were allowed to remain uncorrected. The most annoying are upon page 225—Article, "Thallene," which should be corrected to read "Prof. Horsford"—"a green solid" and "the crystalline form." "[From whence the first tar on which Prof. Morton experimented was derived.]" This last clause should not have been in parentheses, as it was an editorial remark, not a quotation.

Chemistry, Physics, Technology, etc.

NOTES ON ENGLISH CHEMICAL MANUFACTURES.

By S. Cabot, Jr.

[From the *American Chemist*, July, 1876.]

To give an account of the chemical advance, even during a few years, in a great country like England, is no easy task, if only in a sketchy and superficial manner. Nevertheless, having had very good opportunities of seeing some of the newest processes in use in England and Scotland, I propose to run through my note books for the benefit of your readers, leaving out many particulars which would not be interesting to any but specialists, and many which are parallel to our American methods.

Sulphuric acid seems to be the starting point of almost all the larger chemical industries, therefore we will begin with that. The pure acid is made exclusively from sulphur. In the best chemical works (for instance, Mr. Riley's of Accrington, near Manchester) the sulphur is supplied through a hopper at the top of the furnace, the nitre and strong nitrous vitriol being also let into a cast-iron pan in the exit flue by means of another hopper.

The nitrous fumes are removed from the chamber gases at the end of the set of chambers by the use of a Gay-Lussac tower. Vastly the larger portion of the sulphuric acid made in England is, however, obtained by the combustion of pyrites. In addition to the much smaller first cost of sulphur thus obtained, it is in this case possible to use the Glover's towers, which cause a great saving in fuel. The principle of the Glover's tower is well known, but I will describe them as I saw several in England. They are towers made of acid-proof stone joined together by grooving the edge and then inserting a rubber rod; at the corners these rods are slit, and one is run through the other. The whole is bolted together outside with iron rods. These towers are from 30 to 40 or 50 feet high, and are filled with some acid-proof brick. At the top are two tanks, one contain-

ing chamber-acid, and the other nitrous vitriol from the Gay-Lussac tower. These acids are allowed to flow together down through the tower, while the hot sulphurous acid from the pyrites burners rises up in the opposite direction and carrying some water as steam, and much nitrous acid goes forward into the chambers. Many attempts have been made to use the Glover's tower where sulphur was burned. The reason of failure is that, as Prof. Kopp once told the writer, sulphur can never be raised to the temperature obtained by burning pyrites, as it is volatile at a much lower temperature. The acid as it comes out of the towers is not far from 55° or 60° Bé., and may be concentrated in glass or platinum stills, as is done in this country.

The greater part by far of this acid is, however, used for the decomposition of salt in the Leblanc soda process.

This decomposition of salt is done in hemispherical cast-iron pans, which are connected with absorbing towers constructed much like the Glover's towers, but filled with coke. These pans are separated by a sliding door with a muffle furnace, into which the mass is shoved while still quite liquid, and this muffle is connected with another condensing tower in which a less pure hydrochloric acid is obtained.

There is, however, a new method of accomplishing the decomposition of salt, patented by Hargreaves & Robinson. The process is, briefly, to pass a mixture of air, sulphurous acid and steam through salt in a porous condition, obtained by moistening it and then drying and breaking it up to the required size. This has the obvious advantage of doing away with the sulphuric acid chambers entirely.

The operation is performed in immense cast-iron chests heated on the outside with coal fires, and the gas from pyrites burners is put in at the bottom of one with an excess of air and some steam, it is then taken in at the top of a second one, and so on; this is of course changed about as one after the other of the chests is discharged.

The hydrochloric acid is very strong; indeed Mr. Hargreaves told me, in showing me the condensing apparatus, that in the first pipes it was stronger than by the ordinary method.

The sulphate of soda formed seems to be of good quality, and manufacturers are looking with much interest to see the result obtained by several large establishments running on this plan.

The salt in its porous condition is thought to act catalytically, causing the sulphurous acid (SO_2), which, however, would not occur

without the presence of steam to form (H_2SO_4) sulphuric acid, which in turn reacts on the salt to form (Na_2SO_4) sulphate of soda and (2HCl) hydrochloric acid.

In the preceding paragraphs I disposed, rather summarily perhaps, of the various methods of manufacturing sulphate of soda and muriatic acid. I now propose to take up the various products of the latter acid, and give a sketchy account of the methods in use in England for the manufacture of chlorine and chloride of lime.

The two prominent, almost universal, methods of producing chlorine are by the Weldon and the Deacon processes. The Weldon process is, properly, only a method of regenerating the oxide of manganese from the chloride of manganese, formed by the action of the muriatic acid on natural binoxide of manganese.

By far the larger portion of the chlorine manufactured in England is produced under Weldon's patent, 101,600,000 kilograms, or over two hundred million pounds of chloride of lime, having been put on the market during the year 1874 to 1875 in England alone.

I had the good fortune to make the acquaintance of Mr Weldon, and with him made an excursion of a day to some of the large works at St. Helen's, near Manchester, in one of which I saw his process in operation to great advantage.

The native binoxide of manganese is decomposed in large sandstone chests with muriatic acid; to assist the operation steam is introduced through a small (earthenware) pipe. The chloride of manganese is run into a large stone reservoir while still hot. Here it is treated with a sufficient quantity of finely powdered limestone to neutralize all excess of acid; this throws down any iron that is present as the carbonate of the peroxide. The clear liquor is then pumped into the tanks, where it is mixed with an excess of hydrate of lime. It is then warmed to 55° or 75° Cent., and then a powerful blast of air is blown through pipes which open in fine jets at the bottom. The protoxide of manganese is hereby oxidized to the binoxide, which unites with the lime to a feebly combined acid manganite of the composition, $CaMnO_3H_2MnO_3$, or $\frac{Ca}{H_2}\Big\rangle(MnO_3)_2$. This compound is a brownish black paste which sinks to the bottom, while a clear solution of calcic chloride remains above it. This calcium chloride is sometimes treated with sulphuric acid to obtain precip-

itated calcic sulphate (Paris white) for papermakers, etc. The sediment of bi-manganite of lime is run direct into the chests of sandstone, in which it is treated with its equivalent quantity of muriatic acid. It is, however, in a state of exceedingly fine division, and therefore requires less heat to produce the reaction. The calcium of the compound (bi-manganite of lime) requires, however, two equivalents of muriatic acid, lost in the chloride of calcium, which is usually run away for the benefit of the fishes.

$$CaOH_2O(MnO_2)_2+14HCl= \\ CaCl_2+2MnCl_2+8H_2O+8Cl.$$

It is evident from examining the above formula that not only two equivalents of muriatic acid are lost on the calcium, but four more are lost on the chloride of manganese (afterwards changed to chloride of calcium by the addition of lime). In an attempt to avoid these losses Mr. Weldon has invented and patented another process, which I will only briefly notice, as it has not as yet proved a success in a commercial sense, I believe.

In place of lime in the regeneration of the chloride of manganese, he proposes magnesia (MgO). The solution of $MgCl_2$ (chloride of magnesium) with suspended bi-manganite of magnesia, is evaporated. As it approaches dryness muriatic acid is given off, which is condensed for further use; then a stream of air is let in and the mass is roasted in a muffle, whereupon the manganite of magnesia reacts on the chloride of magnesia and gives chlorine (mixed with air). After roasting with an excess of air, the mass becomes changed to manganite of magnesia. This is treated with aqueous muriatic acid, whereby chlorine and a mixture of chlorides of manganese and magnesia are produced, which latter mixture is treated as before. Theoretically this process is subject to no loss of chlorine, but there are many practically important obstacles to its success—the difficulty of evaporating chloride of magnesium without destroying the vessel containing it, etc. Both of Weldon's processes are at a glance nothing but indirect methods of decomposing hydrochloric acid by means of the oxygen of the air. We now come to a direct method of accomplishing the same result. This we see exemplified in Deacon's chlorine process.

This process I had the good fortune to see in Deacon's own works. It depends upon the decomposition of hydrochloric acid at high

temperatures by the oxygen of the air in the presence of a salt of copper. The gas from the converting furnaces mixed with air is passed through chambers heated outside to between 400° to 500° Cent., and filled with earthenware balls moistened with a solution of sulphate of copper. The mixture is decomposed according to the following reaction: $\underbrace{N+O}_{\text{air.}}+2HCl=H_2O+Cl+N.$

The mixture of nitrogen, chlorine and steam is cooled, whereby the steam is condensed, then washed with water to remove any excess of acid which has not been decomposed, and then passed into the lime chambers, which must have a large surface on account of the dilution of the chlorine by nitrogen and air.

The great drawbacks to this process are: first, the quantity of hydrochloric acid (HCl) left undecomposed; second, the great dilution of the chlorine. The consequence is, that most large works—Deacon's own, for instance—use both the Weldon and the Deacon process. It appears to me that the two might be combined to advantage by passing the gas from the Deacon converter through a tower filled with native manganite in lumps, and regenerating the chloride of manganese formed by the action of the muriatic acid left undecomposed in the converters by the Weldon process.

There is one other process, in use at Tennant's works in Glasgow, in use at the time I was there, at least, wherein the manganese liquor was precipitated boiling hot, and under some pressure, with powdered limestone. The precipitated carbonate of manganese was then heated on trays in ovens with a supply of air which changed the manganous carbonate to manganic oxide, with the evolution of carbonic acid. This process, however, has not been introduced into the newer portion of Tennant's works, in which Weldon's process has been substituted.

At Tennant's, also, a part of the chlorine was produced by acting on a mixture of salt and nitrate of soda with sulphuric acid. The mixture of chlorine and nitrous acid was passed through strong sulphuric acid, which absorbed the nitrous gas, while the chlorine passed forward to the lime chambers. The nitrous vitriol was used in the Gay-Lussac towers.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS DURING THE LAST TEN YEARS.*

By Dr. A. W. Hofmann.

From the *Chemical News.*

[Continued from Vol. cii, page 278.]

Weldon's process, lastly, is worked more rapidly than the old method, and requires a smaller number of sandstone troughs, though the latter advantage is out-balanced by the cost of the oxidation apparatus. The productive power of a sand-stone apparatus was, on the old process, 1270 kilos. of chloride of lime weekly; whilst on Weldon's method in Alhusen's works, at Newcastle, the weekly production is 4572 kilos. In the same establishment four hours are required for the oxidation of 2500 kilos. of peroxide of manganese, being at the rate of 115 kilos. oxygen per hour.

The cost of the process in England compared with the old method may be seen from the following statements of Weldon's:—

Per 1000 kilos, chloride of lime—

Weldon's Process.—Labor, 10s. to 17s.; coal, 750 kilos.; lime, 1400 kilos.; lime-stone for saturating the excess of acid, 250 kilos.

Old Process.—Labor, £2; manganese, £6; lime, 700 kilos.

The use of Weldon's process is decidedly increasing. In the beginning of 1874 the annual produce in England on this system was 50,800,000 kilos. chloride of lime, and plant for the further production of an equal quantity was in the course of erection, whilst the previous annual production on the old system did not exceed 91,440,000 kilos. In Germany the "Silesia" establishment at Saarau has carried on Weldon's process with advantage for several years. In Belgium, according to Mr. Weldon's account, the works at St. Marie d'Oignies, near Charleroi, have introduced the process. In France the same step has been taken by the St. Gobain company, whilst Kuhlmann,** Merle, and other manufacturers are preparing to

* "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

** On September 18th, 1874, I found in the establishment of M. Kuhlmann, no preparations for the introduction of Weldon's process.—A. W. H.

adopt the new method. In Saarau, where, as already mentioned, Weldon's process has been in operation for some years, it is carried on exactly as above described. The consumption of lime for the regeneration of material for 100 kilos. of chloride of lime is 70 to 75 kilos. inclusive of the sediment which becomes useless in preparing milk of lime. To regenerate enough for 2500 kilos. chloride of lime air is forced in for five to five and a half hours, and from 75 to 80 per cent. of the manganese present is converted into peroxide. The air-pump employed works with 45 horse power, and has a cylinder of 7·32 c.m. in diameter, and 94·16 in height. The piston makes 40 strokes per minute. The loss of peroxide of manganese at Saarau amounts to about 10 per cent. (von Kulmitz).

The above described process for the regeneration of manganese residues has one deficiency. A portion of the hydrochloric acid is used to saturate the lime of the calcium manganite, and both lime and hydrochloric acid are generally allowed to escape in the almost worthless state of chloride of calcium. To obviate this defect Weldon has planned a modification of his process, which renders it practicable to obtain as much as 62 per cent. of the hydrochloric acid employed in the form of free chlorine, whilst only a small quantity of chloride of calcium is formed as a by-product. He attains this result by decomposing the manganese solution, not with lime, but with magnesia. For this purpose the process is modified as follows:—The liquid derived from the evolution of chlorine out of magnesium manganite, containing chloride of magnesium and manganese, is evaporated at first in a pan, and then in a kind of muffle, whilst a current of air is constantly passed through. Towards the end of the evaporation the chloride of magnesium, under the influence of watery vapor, yields hydrochloric acid, which is condensed. After the liquid has been evaporated to a certain consistence the salts are drawn upon a hearth, where they are roasted in a current of air. Here chlorine is evolved, diluted with air, and is combined with milk of lime in a scrubber, whilst manganite of magnesium remains behind. The latter is then used with hydrochloric acid for the development of chlorine, and passes again through the same rotation as a mixture of chlorides of magnesium and manganese. The hydrochloric acid, which is given off about the end of the evaporation, is exactly sufficient to evolve concentrated chlorine from the solution of chloride of lime, into which the diluted chlorine obtained by roasting the residue from the evapo-

ration has been transformed. Hence only that part of the hydrochloric acid is lost which is consumed in decomposing the hypochlorite of lime, whilst 62 per cent. of the chlorine which enters the process in the form of hydrochloric acid is utilized in the free state. In this manner it is possible to obtain 1000 kilos. chloride of lime with the hydrochloric acid evolved from 700 kilos. of common salt. The magnesia and manganic oxide are not consumed, but merely play the part of transferrers of oxygen.

Preparation of Chloride according to Deacon.—If Weldon has succeeded in preparing chlorine from hydrochloric acid in a continuous process without, theoretically at least, requiring more than one initial charge of native manganese, the problem of converting hydrochloric acid into free chlorine, without the formation of any by-products, has been much more completely solved by Deacon.

It has been long ago proposed to utilize for the manufacture of chlorine the well-known property of cupric chloride to be decomposed on heating into chlorine and cuprous oxide, which latter in a current of air yields copper oxychloride; but the experiment was never carried out on the large scale. The same applies to the fact, likewise long ago known, that hydrochloric acid mixed with air, and passed over ignited porous bodies is partially converted into chlorine and water. Deacon has succeeded in founding upon the combination of both these reactions a process, which enables us to obtain chlorine continuously without the formation of any troublesome residues whatever.

Deacon observed that the decomposition between hydrochloric acid and oxygen takes place at a far lower temperature if the gaseous mixture, instead of passing simply through ignited tubes or over porous substances, is conducted over heated salts of copper, lead (except the sulphate), or compounds of manganese. The copper salts were found most effectual, so that when a mixture of hydrochloric acid with an excess of atmospheric air was passed over porous bodies saturated with sulphate of copper and heated to 370° to 400°, all the hydrochloric acid was burnt to chlorine and water. In this reaction, which begins at 260°, the sulphate of copper remains unchanged if the temperature is not raised too high. Not till 425° does the formation and volatilization of chloride of copper begin. The permanence and the efficacy of the sulphate of copper can be increased by the presence of certain salts inactive in themselves, such as the sulphates of potash and soda.

A number of experiments conducted by Deacon in concert with Hurter and Carey, since the year 1867, have led to a knowledge of the conditions of the reaction of air and hydrochloric acid in presence of salts of copper.*

1. The quantity of the hydrochloric acid decomposed by a molecule of copper sulphate in gaseous mixtures of similar composition at the same temperature depends on how often the gaseous molecules pass through the sphere of action of the copper salt.

2. At all speeds of the gaseous current in long tubes of the same section, the opportunity for action in one and the same time is invariable.

3. In long tubes of different sections the opportunity of action is equal when the velocities of the currents are inversely as the squares of the diameters of the tubes.

4. In porous masses the efficacy increases directly as the speed.

5. Other conditions being equal the quantity of hydrochloric acid decomposed varies as the square root of the number expressing the proportion of the hydrochloric acid and oxygen.

6. At very high temperatures a certain quantity of chloride of copper is formed, but its amount stands in no proportion to the chlorine liberated.

7. The efficacy of the copper salt extends to gas molecules not in contact with the salts; the decomposition of the hydrochloric acid takes place, therefore, under conditions in which a material exchange between the copper salt on the one hand and the hydrochloric acid and air on the other cannot take place.

Without entering upon the experiments made to explain the efficacy of the copper salt we turn to the method of the practical execution of Deacon's process as hitherto carried out.

The hydrochloric acid is either prepared from salt and sulphuric acid in a common salt-cake furnace or from previously prepared aqueous hydrochloric acid. On a small scale the latter is preferable, as in this manner it is easy to produce a current of hydrochloric acid of always equal strength, whilst the evolution of hydrochloric acid in the preparation of salt cake is very rapid at first, and subsequently becomes slow. On the large scale this difficulty is met by allowing several salt-cake furnaces to work in a series, so that when the evolu-

* Henry Deacon. "On Deacon's Method of Obtaining Chlorine Illustrating some Principles of Chemical Dynamics." *Chem. Soc. Journ.*, 1872, 725.

tion slackens in one, the activity of the next commences. The gas obtained in one or other manner is at once mixed with a quantity of air containing more oxygen than suffices to convert all the hydrochloric acid into chlorine. It is then conducted through heated U-tubes of cast-iron, which communicate to it the temperature required for the process. The composition of the gaseous mixture can be regulated at any moment by a small air-pump which, at every piston stroke, drives a certain volume of gas through a standard solution of soda colored with litmus.

From the heated tubes the gaseous mixture passes downwards into an almost cubical tower whose interior is filled with wall-stones arranged like a grating, and whose sides are traversed by flues, which keep up the temperature favorable for the process. The heat here, as in all other parts of the apparatus, is regulated by metallic pyrometers. The tower fitted up with stone blocks (the Regulator) serves to take up the excess of heat from the gaseous mixture, if the temperature has been carried too high, or to impart heat to it if the proper degree has not been reached. Recently, however, Deacon considers the regulator as unnecessary.

After the mixture of hydrochloric acid and air has left the regulator, by its basis, it arrives in the decomposing furnace. This consists of a cast-iron box in which are nine chambers arranged in a horizontal plane, each of them provided with a grate or false bottom at its lower part. Upon this grating stand, in the first, and also in the second chamber, vertically arranged drain-pipes which have been plunged into a hot concentrated solution of 2 mols. copper sulphate and 3 mols. sodium sulphate, and then dried. The remaining chambers are filled with fragments of bricks or balls of clay (1·5 centimetres) which have been treated in the same manner with sulphates of copper and of soda. The entire furnace is surrounded with an air jacket and this again with a screen of masonry traversed by flues, which has the object of keeping back a part of the heat which would otherwise be lost by radiation. Another portion is supplied by the heat generated in the process by the combustion of the hydrochloric acid. The above-mentioned vertical drain-pipes serve to prevent the apparatus from being choked up with oxide or chloride of iron.

(To be continued.)

JOURNAL

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OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

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EDITORIAL.

NOTICE.—The publication of the JOURNAL is made under the direction of the Editor and the Committee of Publication, who endeavor to exercise such supervision of its articles, as will prevent the inculcation of errors or the advocacy of special interests, and will produce an instructive and entertaining periodical; but it must be recognized that the Franklin Institute is not responsible, as a body, for the statements and opinions advanced in its pages.

The United States International Exhibition of 1876.—The prominent event of the past month in the annals of Science and the Mechanic Arts, has been the closing of the Centennial Exhibition, which occurred on the 10th.

The ceremony of closing wanted the imposing character of that which accompanied the opening; but even a larger concourse of people were upon the ground (115,000 were stated to be present). A continued rain prevented the collection of an audience which was to have been comprised of Commissioners and Judges, and officers of the Exhibition, with numerous especially invited guests—arrangements having been made to accommodate, within hearing distance of the speakers, about 10,000 persons, in the same way that this number participated in the opening—but the storm caused the substitution of the Judges' Hall, where, in the presence of about 1,500 spectators (who attempted to listen to the closing congratulatory

addresses), the President of the United States, at 4 o'clock in the afternoon, declared the final closing of the Exhibition, and gave at the instant the signal for the motion of the machinery to cease.

Of the success which has attended the Exhibition in its inception, in each stage of its existence, in its closing scene, at once financially and in good feeling, its excellence in display and in entertainment, in the satisfaction it has given to exhibitors and to visitors, and, not less than all, in the gratification afforded not only to Philadelphia, but to the country, and also of those foreign nations who so generously aided—of the success of the Centennial Exhibition in all these points, there is but one acclamation.

In the remarks which were made (in the JOURNAL, Vol. CI, p. 361), to record the opening of the Exhibition on the 10th of May, it was anticipated that the *novelties* in the mechanical department, of process or production, which were attractive to the general observer, or would have possessed interest to the popular reader, would prove very infrequent. The most careful seeking of the numerous popular magazines and newspapers, whether published here or abroad, has failed to provide for their readers any large number of brilliant or even entertaining descriptions or illustrations; while the higher technical periodicals have had recourse to historical information to supplement the subjects they have undertaken to describe. It is an undoubted fact that the great attraction of all classes at this Exhibition, has been the artistic display. Pictures, statuary, vases, jewelry and carvings, decorations, laces, ornamental wares of all kinds, called for crowds of spectators; while even in the machinery exhibit, except the common shows of water fountains, fancy weaving, fancy wood-sawing, pretty mechanisms of various kinds, always attractive to spectators of all ages, only walking, unobservant throngs were to be seen. It is not that these minor exhibits grouped together, and that the interested throng of persons is not a pleasant spectacle, but what is to the purpose for the editor of a mechanical and engineering journal, is that they do not afford material for his columns.

As was asserted in the editorial before referred to, many of the novelties which became within a brief time prominently notorious to the visitors of the Exhibition, were by no means noteworthy. Trivial shows and productions were rewarded by popular attention to the utmost. The crowd sought entertainment rather than instruction, and in the mechanical devices, found it in anything to wonder at, rather than in anything to be studied, comprehended and

learned. The same taste for surprises in an individual experience, in visiting and examining for one's self, is carried to the gratification to be derived from descriptions of what was to be seen; so that the general writer whose sole purpose is to interest his readers in a magazine account was able at all times to produce an entertaining article, where the careful observer would be unable to discover in the objects on exhibition, much of either novelty or merit—certainly little of either which would be instructive to the practical man.

But aside from these minor displays, there was a very large and satisfactory exhibit of all kinds of working machines in general use—engines, machine tools, saw mills, agricultural machinery, etc., etc.; although the absence of machinery of special manufacturers was even more marked than in any previous international exhibitions. But this exhibit as a very general rule was comprised, so far as it posessed excellence, of the current articles of sale—articles well known to most technical readers, and such as had been repeatedly exhibited and described; upon which, if any improvements did exist, none but those conversant with the particular applications would discern them; they were so completely improvements of detail—while the improvements, when detected, were found to be mere special applications of well known devices, possessing little interest except to the very few who employed the machinery as a matter of business. The opinion was expressed that the examination of the judges would bring out the most striking novelties in mechanism, but this expectation has been frustrated by the action which has awarded prizes to all. And it is to be regretted that no means have been otherwise provided for giving publicity or award for especial merit.

Possibly relief of responsibility on the part of the Judges and of the Commissioners, and possibly, also, good feeling on the part of the exhibitors, have been promoted by the system of seeking for something commendable in every exhibit and awarding a bronze medal for it; but in the procedure, both the judicial character of the judge and the intrinsic value of the prize has disappeared. This general distribution and establishment of level of merit will scarcely meet the approval of even those competitors whose exhibits were below the standard of award, whereon the exhibition, or common usage, may have created a standard. It is a prize and not a commendation that all competitors seek. Much of the outcry against the partiality, unfairness or absolute injustice of the awards at previous exhibitions, is well known

to be mere advertising of commodities,—the pure seeking for notoriety by appeal to the public by printed circulars and through notices in the newspapers. It has been found safer to abuse the judges than to depreciate the value of a competitor's wares, in the legal point of view of the two transactions.

The race will have its excitement and be thronged with competitors, although it be not for the swift. If it had been generally known that no prizes for comparative excellence or novelty were to be given, it is very doubtful if even national or sectional pride would have filled the halls of exhibition. Throughout those miles of passages every object of display was there, not alone for admiration, but for comparison, for selection. What was beautiful to the eye, grotesque to call for observation, farcical to be laughed at, easy to comprehend, crowds found out and enjoyed in a general way; but that appreciation which recognized what constituted excellence in thus producing enjoyment; and more than all this, the appreciation of what constituted excellence and merit in those exhibits which are not merely prettinesses, belonged to competent judges in the several and multifarious branches of science and the arts. The declaration of the result of comparison was one of the obligations of the management of the Exhibition, and the failure to give such a declaration in the form of capital prizes is a disappointment both to the public and to the competitors. Without such prizes great exhibitions lose much, if not most, of their value as means of advancing science and the arts.

Anthracite Coke.—A small specimen of anthracite coke has been given the editor by Doct. C. M. Cresson. It is said to have been coked near Pittsburg from equal parts of anthracite and bituminous dust or slack. The density is about 0·85 and the light spongy aggregation much resembles gas coke in texture, but with more bright grains of unchanged anthracite particles. Its strength is not great, and it is somewhat uncertain if it would bear transportation better than most gas coke does, and consequently it would be found profitable, if not necessary, to make the coke at the works where it is to be used as fuel.

Doct. Cresson's test of this coke gave :

Ash, ...	17·6	per cent.
Sulphur, ...	0·2466	"

and a heating power of 8·08 pounds of water evaporated per pound of coal.

Franklin Institute.

HALL OF THE INSTITUTE, Nov. 15, 1876.

The stated meeting was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers, in the chair.

There were present 110 members and 7 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 19 persons were elected members of the Institute; that the award of the Scott Legacy Premium and Medal were awarded to Messrs. Chambers, Bros. & Co., for their Brick-making Machine; and that the following donations were made to the Library:

Outline history of Japanese education prepared for the Philadelphia International exhibition, 1876, by the Japanese Department of Education. New York, 1876. From D. Murray, Commissioner.

Meylert's rational method of drying and preserving food. From A. P. Meylert, M.D.

The Russian system of shop-work instruction for engineers and machinists. Read before the Mass. Institute of Technology, Aug. 21, 1876, by J. D. Kunkle. From the Author.

Report on the Twelfth exhibition of the Massachusetts charitable mechanic association, Boston, Sept. and Oct., 1874. From the Association.

French metric system of weights and measures, by J. W. Nystrom, C.E. From the Author.

On the state of the Iron Manufacture in Sweden at the beginning of 1876. From S. Westergood.

Norwegian special catalogue for the international exhibition at Philadelphia, 1876. Christiania, 1876. From the Norwegian Department.

Jetty System, explained by Jas. B. Eads, St. Louis, 1874. Report on the Mississippi Jetties, by Jas. B. Eads, Chief Engineer, Aug. 18, 1876. Letter from J. B. Eads to the Secretary of War, with Appendices. New Orleans, 1876. Physics and hydraulics of the Mississippi river, Report of the U. S. Levee commission, reviewed by Jas. B. Eads, C.E., St. Louis, Feb. 19, 1876, New Orleans, 1876. From Jas. B. Eads.

Antique Jewelry and its revival, by Signor Alessandro Castellani (of Rome). From J. H. Coates, publisher, Philada.

Science made easy; a series of familiar lectures on the elements of Scientific Knowledge most required in daily life, &c., &c., by Thos. Twining. London, 1876. From Chapman & Hall, publishers.

Seventh annual report of the Geological survey of Indiana, made during the year 1875, by E. T. Cox, State Geologist. Indianapolis, 1876. From E. T. Cox.

Mittheilungen der K.k. Geographischen Gesellschaft in Wien, 1875. XVIII. Band (der neuen Folge VIII). Wien, 1875. From the Society.

Lawrence Water Works. Reports on the trial of duty and capacity of the pumping engines, May, 1876. From E. D. Leavitt, Jr.

History, manners and customs of the Indian nations, who once inhabited Pennsylvania and neighboring states, by Rev. John Heckewelder, &c. Philada., 1876. From the Historical Society of Penna.

De la transmission et de la distribution des forces motrices a grande distance, par A. Achard. Paris, 1876. From the Author.

Specifications and drawings of patents issued from the United States patent office for May, 1876. From the Patent office.

South Australia: Its history, resources, and productions, edited by Wm. Harcus, Esq. London, 1876. From S. Davenport, Centennial Commissioner.

Geological survey of Kentucky: Chemical examinations of ashes of Hemp and Buckwheat plants, with remarks, &c., &c By Robert Peter, M. D., Chemist to the survey. Pt. 3, Vol. 2, 2d series. From Robt. Peter, M. D.

Instructions to Observer-Sergeants, Signal service, U. S. A., on duty at stations. Washington, 1875. Practical use of meteorological reports and weather maps. Washington, 1871. War Dept. weather map signal service, U. S. A., for Oct., 1873, and January—December of any year. From Albert J. Meyer, Brig. Genl. and Chief Signal Officer U. S. A.

Les Promenades de Paris, Bois de Boulogne, Bois de Vincennes, Parcs, Squares, Boulevards, par A. Alphaud. Paris, 1867–1873. From Dr. Chas. M. Cresson.

The Secretary presented his Report, embracing Mr. T. J. Lovegrove's new Boiler Tube expander; Saml. L. Harrison's car axle for turning curves without friction; Dr. A. P. Meylert's apparatus for drying and preserving food; Saml. Murset's Fire Escape; and a governor for the prevention of racing in marine engines, the invention of Mr. A. Adamson, Past Asst. Eng., U. S. N.

Mr. Robt. Briggs gave an illustrated description of Hipp's chronograph, prefacing it with a short paper on the general subject of divisions of time.

The Secretary gave notice that the catalogue of the library is now complete, and is for sale, bound in cloth, at $2.00 per copy. He also again called the attention of members to the elementary series of lectures, which commence on to-morrow evening, and urged members to do all in their power to secure the attendance of those intended to be benefited, and to encourage such persons by coming themselves.

Under the head of deferred business was taken up the motion of Mr. Jones, relative to the Majority Report on the metric system of weights and measures, the original motion having been divided into three separate resolutions, as follows:

1*st*, *Resolved;* That the Reports of the majority of the committee on the subject of the metric system of weights and measures be adopted.

2*d*, *Resolved;* That a copy of the same be transmitted to the Boston Society of Civil Engineers.

3*d*, *Resolved;* That the Report of both the majority and of the minority of the committee be printed in the JOURNAL.

The general subject was discussed by Messrs. Orr, Briggs and Tatham, when Mr. Briggs moved to lay the whole subject on the table, which was lost.

After considerable discussion the previous question was called, and sustained by a standing vote of 39 ayes to 31 nays.

The Chair then put the first resolution, and it was adopted by a standing vote of 41 ayes to 39 nays.

The second resolution was also adopted.

The mover stated that as both reports have already been published in the JOURNAL,* by authority of the Committee on Publication, it was not necessary that the third resolution should be adopted; and on putting it to vote it was lost.

The proposed amendment to Sec. 2 of Act VII of the By-laws, offered by Mr. J. J. Weaver, and postponed from the last meeting, was then taken up, and was discussed by a number of members.

The previous question was called and sustained.

The question of the adoption of the proposed amendment being put to vote, it was lost.

On motion, the meeting adjourned.

J. B. KNIGHT, *Secretary.*

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* See Vol. ci, pp. 370–384, June, 1876.

Tube Expanding.—The tube expander of Mr. T. J. Lovegrove, exhibited by the Secretary at the meeting of the Institute, is remarkable as a novel use of the elasticity of form of india rubber. The expander is simply a ring or collar of india rubber, fitting closely upon a bolt of iron and secured between two discs, inserted in the end of the tube to be set or expanded, and held or clamped firmly in place. This collar is then compressed, in the direction of its length, by means of a screw on the bolt, which moves one of the discs, and the effect of this endwise compression is to expand the rubber ring in radial direction, producing a hydrostatic pressure on the inside of the end of the tube, proportionate, and almost equal in value, or amount, to the endwise pressure exerted by the action of the screw on any unit of surface of the rubber collar. This result proceeds from the fact that, while rubber has much elasticity of form, it is almost wholly incompressible in volume. In fact it is one of the most incompressible solids known, if not *the* most incompressible. It very closely approaches to water in this regard, and seems to be devoid of either pores, or particle elasticity, which pertains to other solid bodies however composed. (It is probable that all liquids in common with water are incompressible except in some slight degree.) The idea of taking advantage of this quality of rubber for obtaining a hydrostatic pressure, while its tenacity prevents its escape, or flowing away, at the joint between the discs and the inside of the tube, is decidedly novel, and is thought to be original with Mr. Lovegrove.

Flooding of the Thames Tunnel.*—Underground railways in the metropolis are all liable to be flooded with water, and to prevent this, continuous pumping in certain districts is required. For example, on the Metropolitan District Railway, steam pumps are in operation night and day, at the Victoria and Temple stations. The East London Railway is no exception to the rule, and owing to the failure of the pumping machinery at Deptford-road, the line has been rendered impassable for a few days. The facts appear to be as follows:—On Monday morning, at the Deptford station, it was discovered that water was percolating through the gravel from the new dock of the Surrey Commercial Company on to the permanent way. The inflow was not a large one, but the pumps at Deptford-road,

* From *The Engineer*, London, October 27th, 1876.

which, in order, would have been able to cope with it, were in such a state of disrepair as to be useless. From Deptford-road station there is a rather steep gradient to Rotherhithe, where the Thames tunnel commences. There is a similar rise from Wapping towards Shadwell, so that the tunnel being the lowest part of the line, and the flow of water being unchecked, it soon rose to such a height between Wapping and Rotherhithe that is was deemed advisable to stop the through traffic. There are pumps at Rotherhithe as well as at Deptford-road, and the former would have been quite sufficient to keep out the water, but they, like those at the latter place, happened to be out of order, and after being at work for a little time they broke down altogether. Through traffic was suspended at 11.20 on Monday morning, but the tunnel pumps, though out of order, were able to reduce the height of the water by night, so that the two last trains were taken through; but soon afterwards the tunnel pumps became unfit for further service without repairs. These repairs are now being carried out, so that in the opinion of the railway officials the resumption of the traffic depends upon the time it will take to place them and the others at Deptford in order. The rumor that the crown of the tunnel beneath the London Docks had given way is untrue; in fact, the trains have been running beneath the basin to and from Wapping, and on the other side of the river between Rotherhithe and New Cross, ever since the stoppage of through traffic, and as if that check had never taken place. It will be remembered that the line runs close to the new Surrey Commercial Dock. This dock was partly filled ten days ago. What will happen to the railway when it is quite filled remains to be seen. According to the latest reports the line had been cleared for the present.

Grindstones.—None of the processes of the mechanic, however commonplace they may seem, are below the universal law of being required to be learned. Either practice or instruction must teach the beginner; intuitive mechanics, who trust to their own experience, are likely to have a deal of it, before they attain a capability that is trustworthy in any branch. A little pamphlet on grindstones and grindstone fixtures, issued by J. E. Mitchell, of this city, as an accompaniment to an advertising exhibit at the Centennial Exhibition, is a striking exemplification of the desirableness of a *literature* on a special subject. Our grindstones come from England, from

Scotland, from Nova Scotia, from New Brunswick, from Ohio, from Michigan. They are found in the sand rocks of different ages—they are suited to various uses—they must have special treatment to render them valuable for particular requirements. It is as much of an art to run a grindstone for any purpose as that of the smith, the machinist or the plumber, and the occasional use of a stone by other mechanics, presents to them as many difficulties as the taking up of another trade, which mechanical engineering sometimes requires. It is the ability to makeshift in case of necessity that makes at once a skilful and skilled workman.

Mr. Mitchell's instructions as to how to hang a stone, how to keep it in order, how to keep it from getting out of order, are the result of a lifetime of knowledge of the *experience* of those whose neglect, ignorance or conceit has found out the what to do and what not to do with a grindstone. It is stated that they should always be hung by plates which clamp the sides of the stones, in lieu of being keyed and driven by a square hole in the centre,—that they should be turned all over to run true,—should be abundantly supplied with water when grinding, but never permitted to stand in water when not running. That large stones should be kept true by the free use of the hacker, and small ones by the constant use of the turning tool. The bresting of grindstones is attributed generally to the allowing a part to stand in water when not in use. Great care should be exercised in examining a stone for defects before hanging it. The sides and edge should be washed off with water and a broom, and if any crack be discovered, the stone should be rejected.

The use of the grinding processes in the machine shop is rapidly increasing. Rolling, stamping or squeezing metal into shape, and to exact size, without calling for the planing, or turning, or milling operations, are practices of great economic value in mechanism. Cutlery of all kinds, knives, forks, scissors, scythes, besides many parts of engines and other machines, are forged to exact dimensions, and the emery wheel, or the grindstone and hone, gives the finish. Work made in this way is really better than that which has been wrought out of the solid. As the grindstone is the important element in this kind of workmanship, a reference to Mr. Mitchell's pamphlet is one of the best ways to learn "how to use a grindstone."

TOUGHENED GLASS:

Notes on its Manufacture.*

From *The Practical Magazine* of London, for October, 1876.

The following notes on the manufacture of toughened glass are the result of a visit to the factory at Choisy-le-Roi by M. Bourée. The process employed is that of De la Bastie. M. Bourée says that the result of the hardness of the glass being above all things a question of care, he enters into the details, it may seem, somewhat minutely; but he thinks it necessary in one who wishes to give an exact account of the process.

Theory of Toughness.—Toughness is a quality obtained by suddenly cooling a body after it has been heated. Glass is toughened by immersing it when red hot in a bath of a given temperature; that is to say, the glass, after having received its definite shape, instead of being placed in an oven where it gradually cools, after having gone through the operation of annealing, is, on the contrary, again heated to redness and rapidly plunged into a bath of grease. The toughness is the more effective in proportion to the excessiveness of the heat and the rapidity of the cooling. The cooling is obtained by the difference of the temperature of the glass at the moment of immersion and that of the bath. The effects of the toughening are purely physical. The toughening changes the molecular composition of the glass; it becomes less dense, and its fragments, when it is broken, do not contain sharp edges like ordinary glass. Pressed into the flesh it does not wound. This phenomenal metamorphosis will be accomplished under the better conditions the less of cohesion there is between the molecules. The more glass is malleable and approaches a pasty state, the more the molecules are easily displaced to group themselves after a certain law. Glass that has not been brought to a sufficient degree of malleability will be imperfectly toughened, and below a certain temperature will be insensible to the action of the bath; but if too soft it will be distorted. The glass to be submitted to the toughening process should be heated to a temperature approaching that which would alter its shape—

* It should be borne in mind that the degrees of temperature referred to in this article are Centigrade—0° = 32° Fahrenheit. The word "toughened" is here employed, notwithstanding its possible faults of construction, as it has been adopted in this country as a denomination of the peculiar manufacture.

nearly to melting. The more effectual the cooling the greater degree of toughness is attained; but the toughened glass breaks in a bath the temperature of which is too low. The reaction is too precipitate; the displacement of the molecules is produced in too accentuated a manner, and the equilibrium is broken. Within a certain limit the temperature of the bath is subservient to that of the glass. The minimum temperature of the bath in which the glass, heated to almost melting, is susceptible of being toughened must be found. It is to be found by experimenting, and varies:

1. With the composition of the glass.
2. With the form, the thickness, and the dimensions of the article.
3. With the temperature of the glass.

On the Influence of the Nature of the Glass on Toughening.—In accordance with its composition, glass approaching melting, and passing through its different states of malleability by very variable temperatures, the temperature of the bath should be also varied. Repeated experiments will best show. Primarily, it will be necessary to determine the temperature and the nature of the bath that is the most advisable for glass of which the exact composition is known. It may be said in general, that the bath should be warmer in proportion to the softening of the glass being slower. Crystal: All crystal is toughened in a bath of pure grease in a temperature of from 60° to 120° Centigrade. Trials have been made with Baccarat crystal. A crystal composed of 300 parts of sand, 100 of potash and soda, and 50 of red lead, is one that succeeds well in toughening.

Glass: Glass is toughened in a mixture of oil and grease of a temperature varying from 150° to 300°; the more difficulty in melting the glass the higher the temperature employed. The proportions in which lime and soda enter into the composition notably influence the temperature of the bath. Bohemian glass, having a basis of potash, is toughened in a bath of at least 300°.

The Temperature of Crystal varies with the Thickness and Form of the objects.—Shaped pieces of crystal coming from the same crucible, in accordance with their form, their thickness, and their dimensions, require to be more or less reheated before being treated for toughening. The temperature of the bath should be also varied within certain limits. Thick pieces require to be reheated the most, and want the bath a little hotter. Thus at Choisy-le-Roi gas tubes, lamp glasses, &c., are toughened in a bath of 60°; while drinking glasses and goblets, according to their form and dimensions, are

toughened in baths reaching 60°, 65°, 70° and 75°. Water-bottles, dishes, &c., are toughened in baths varying from 75° to 90°.

Composition of the Bath for Glass and Crystal.—The composition of the bath has a notable influence. All liquids are not appropriate for toughening. In water, glass always breaks. Perfectly pure grease and virgin oil, free from all mixture, give the best results. Pure grease is employed for toughening crystal in preference to oil. Pieces toughened in oil attain clearness at much too great an expense. The toughening of glass requiring a bath of a temperature varying from 150° to 300°, pure grease cannot be employed on account of its ebullition. Recourse is therefore had to a mixture of three-fourths of linseed oil with one-fourth of grease. Pure glycerin, or a mixture of grease and glycerin, that will not boil up to 300°, may be employed with advantage in toughening glass. Toughening cannot be properly accomplished in a bath of grease that is not free from impurities or the least quantity of water. For this reason a new grease should not be employed that has not been previously heated for four or five days to a temperature of 150°. It can be used indefinitely afterwards, and the older it is the better. In a factory there should always be, in a fixed place, a constantly heated vat of grease that would serve to replenish the baths. An indispensable condition for the success of the toughening is that the temperature of the glass should be perfectly uniform on all points of its surface.

Means of Conversion for Table Glass.—Glass irregularly heated breaks in the bath, the toughening not being equal the equilibrium of the molecules is disturbed. In table glass the object leaving the hands of the moulder has a nearly uniform temperature in all the points of its surface; it is always hotter at the extremity last fashioned, and reheats more there. In this state it is not susceptible of receiving toughness; not being warm enough it should be replaced in the working-hole, and as deeply as possible, to insure the equal distribution of heat in all its points. In taking it out, the workman must assure himself, before plunging it in the bath, that this condition is fully realized. If the extreme parts appear redder than the others he will wipe them delicately with a piece of paper slightly wetted, and replace the piece in the working hole for a few seconds before toughening. How long the glass should remain in the oven is for the workman to learn to determine. I will meanwhile say that a good workman toughens better with more heat. That piece which, brought to softening, would be deformed in unskilful hands, preserves,

on the contrary, its form perfectly when confided to a trained toughener. It is important also that the temperature in the working-hole should be uniform. This is attained by heating it by burning wood equally distributed on the surface. Currents of air in the factory, which might cool the glass at the moment of toughening, must be carefully avoided.

(To be continued.)

TIMBER NOMENCLATURE.

[From the *Timber Trades' Journal.*]

[Continued from Vol. cii, page 203.]

Thorn, although generally associated with our cultivated hedges, had in its Anglo-Saxon form a more extended meaning. It implied a tree, although not of the first order. In this sense it is used in the "Buckthorn," and the "Blackthorn." From the study of place-names in Mid England, we are led to infer that thorn implied a wood; a portion of Sherwood Forest was known as "Thorneywood chase," and part of Hatfield chase an extensive wood known as "Thorne-waste." Indeed "Thornhills" aud "Woodhills" occur in such order that we are led to the conclusion that they are synonymous terms.

Timber is from the Anglo-Saxon "timber," and "tymber." 1, wood; 2, a tree; 3, a frame structure or a building, From the fact of building being conducted in wood, timbering (*getimbrian*) was the equivalent of building. At the burning of the first wooden church or cathedral at York, in 626, a larger church was ordered to be *getimbrian* of stone. It does not appear to have been a term much used in a territorial sense. Henry II. confirmed the grant of the church of Tymberland to Thurgarton Priory, Notts, which may or may not be the village of that name in Lincolnshire. From this we may infer that the term applied more to the wood in a dead state than to that of the living tree; in which sense it has undergone little or no change.

Tree, from the Anglo-Saxon "treow." 1, a tree; 2, wood; 3, a piece of wood. In the latter sense, it is used in shipbuilding and carpentery, as "cross-tree," "roof-tree," "side-tree," &c. "Treow-wyrhta," the tree or wood worker, was the old term for carpenter be-

fore we borrowed the French one of *charpentier*, and "treow-geweorc," tree work, was the primitive of the now general "woodwork."

Wainscot is a word of doubtful etymology. Bayley says it is from the Belgian "wandschote," wall defence or lining. Ogilvie says it is from the Dutch "wagenschot," which evidently means wagon lining or covering; whereas Loudon says it is from the Dutch "ward," a wall, and "schoten," to suspend. These derivations are evidently sought for, the various authorities having in view the fact of wainscots being largely used in the Tudor and Stuart ages for wall framing or paneling, which appears, probably from being made of oak, to have taken up the name of wainscoting. As wainscots were articles of import centuries before this time, it is highly probable these authors were in error. In the *Liber Albus* of the city of London in the reign of Henry II (1215–1266), we find the following note:—"For every hundred of boards called weynscotte one halfpenny to be paid as custom upon landing at Billingsgate;" and "wainscot" formed items of assessment in the cargoes of nearly every ship arriving in Hull, 2d Henry IV (1400). The writer records these notes to assist in the solution of this knotty term, the accepted derivations of which are in no way satisfactory. It may be further noted that wainscot in the Swedish and German dialects bears the sense or meaning of wall-lining or paneling.

Walnut, a name that occurs with little variation in the German and Swedish dialects, is from the Anglo-Saxon "wealh-knut," the foreign nut. "Wealh" was a term our rude forefathers applied to anything foreign, hence "wealh-men," Welsh-men, the Celtic race formerly inhabiting this country, but driven by them into the fastnesses of the Welsh mountains. The etymology of this word implies that the same people were acquainted with this fruit long before the tree was introduced. Like many other fruit-bearing trees, it is supposed to have been introduced by the Romans, but to have been lost through the neglect they received after the departure of these warlike people, and to have been reintroduced by the monks of the middle ages, who were great gardeners and cultivators.

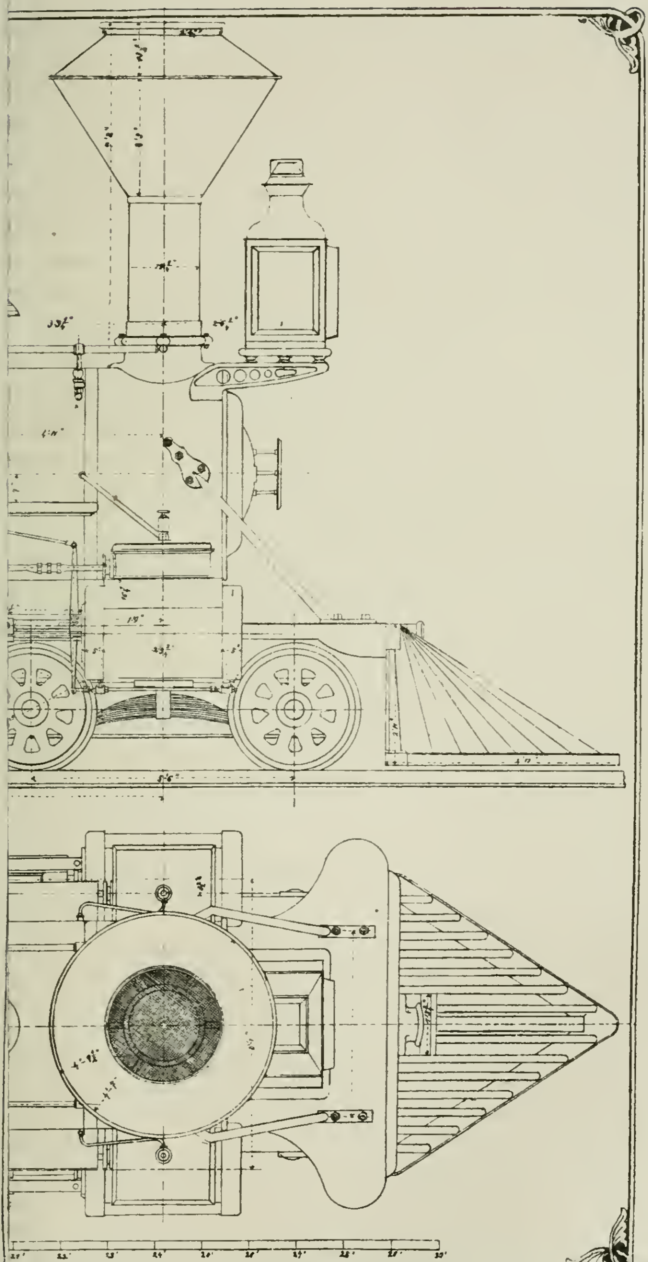
Wood is a grand old Teutonic term. It is the Anglo-Saxon "wude," German "wald," and the Swedish "ved." It means 1, a tree; 2, the substance of a tree; 3, a collection of trees. "Wude-beam" was the primitive term for forest-tree, and "wood-hewer" and "wood feller" of woodman. The mention of this term reminds us of the Scriptural allusion to "the hewers of wood and the drawers of water."

In early times, the calling of wood-hewer was of that importance that it stood for a family name with the followers thereof; hence the common surnames of Woodyeare, Goodyear, &c.; by the same rule the progenitors of the wood-fellers are recognized under the *nom de plume* of Goodfellow. In a territorial sense, "wood" has given its name to numerous families, some of which may be recognized under the corrupted forms of "Good" and "Hood." Robin Hood, the popular myth of the middle ages, is supposed to be a name or term drawn from his calling—"Robber of the Wood," as robbers were called "Robin-men." "Robin" is given in the "Dictionary of Phrase and Fable," as highwayman. Perhaps one of the most remarkable uses of the term "wood" was in application to timber dealers or merchants, whom we anciently called "Wood-mongers," the equivalent of the Swedish "ved-hanlare." The writer has documentary evidence of the use of this serio-comic term in London as early as 1350, and in Hull as late as 1650.

Wright, the short or abbreviated form of "wroughter," a workman, may in conclusion be noticed. It is curious that it has affixed itself to those trades associated with wood; thus evidencing the former importance of these crafts or callings. We have already noticed that ancient "tree-wright" is buried under the modern term of carpenter, but it lives in cartwright, wheelwright, wainwright, plowright, shipwright, and boatwright, which are common as trade or personal names.—*Wm. Stevenson, F.R.H.S., Hull.*

Book Notice.

The Editor acknowledges the receipt of a pamphlet on "Interpolation, or adjustment of series," by E. L. DeForest, Watertown, Conn., privately published. This pamphlet is a continuation of two other papers on the same subject which appeared in the Annual Reports of the Smithsonian Institute, for 1871 and 1873. In this country the interest in *pure mathematics*, either popularly or professionally, is so little developed, that even the Smithsonian Institute is dilatory in publishing; and the author in this instance, fearing a loss of his reward on an original investigation, has issued the present publication. There is no study so engrossing, and *consequently* so pleasant to the student as *pure mathematics*; and especially as its pursuit calls for a high order of intellectual ability, it is to be regretted that the same interest is not taken here as in foreign countries; as it is, however, we can only call the attention of the few of our readers whom it concerns, to this work, which contains some new and interesting formulæ and applications.



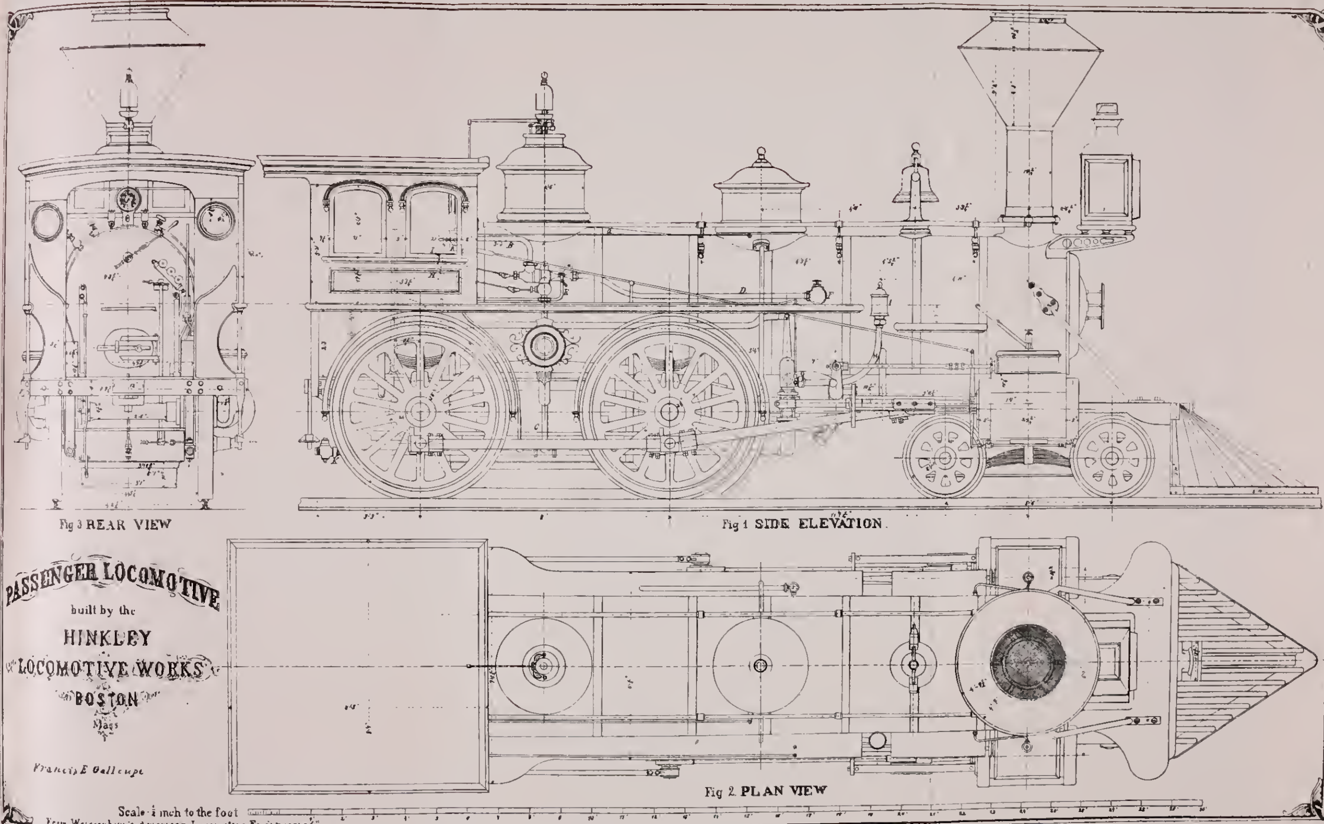


Fig 3 REAR VIEW
Fig 1 SIDE ELEVATION
PASSENGER LOCOMOTIVE
built by the
HINKLEY
LOCOMOTIVE WORKS
BOSTON
Mass
Francis E Gallcupe
Fig 2. PLAN VIEW
Scale ¼ inch to the foot
"From Weissenborn's American Locomotive Engineering"

Plate A.

Civil and Mechanical Engineering.

CERTAIN POINTS IN THE DEVELOPMENT AND PRACTICE OF MODERN AMERICAN LOCOMOTIVE ENGINEERING.

By Francis E. Galloupe, S.B.

[A portion* of a Thesis presented for Graduation in the Mechanical Engineering Department of the Massachusetts Institute of Technology, Boston, May 1, 1876.]

Part I.—An American Passenger Locomotive.

"The locomotive engine," it has been said, "may be selected as the grandest and most important development of modern civilization and human skill." It occupies a prominent position, and constitutes a great and important branch in mechanical or dynamical engineering. In it we deal with dynamical science—the science of motion and of power.

The first impression received by even a casual observer, is that of power. Its condition throughout is that of a transmitter and transmutor of energy. It begins in the furnace, with receiving power, as the motion of heat, from the combustion of coal; transmits it to water and steam, as the working fluid, by means of the boiler; and converts it in the engine into visible motion of masses of matter through space.

In a more limited sense the locomotive engine may be defined to be a machine for converting the expansive force of steam into mechanical work. Its ultimate object is to draw a train of a certain number of cars upon a specified maximum ascending grade at a certain velocity. It consists of two high pressure steam engines, mounted upon wheels, and carrying not only the apparatus for

* In a previous portion were considered the subjects of Force, Heat, Combustion of Coal, Water and Steam. Beginning with a historical sketch, the modern theory of the nature of force, motion and heat, the primary moving force in the locomotive, was treated. The heat of combustion and evaporative power of bituminous coal were then calculated, and the efficiency of steam determined under the ordinary conditions in locomotive practice.

generating and distributing its power, but many adjuncts for the convenience and safety of those who run it, and the public at large.

As it now exists it has more than *two hundred* parts in its anatomy alone, each having its distinct work to do, and all so interdependent that if any one fails, it may involve the others in a general destruction.

A complete discussion of the locomotive would, I suppose, include at least the treatment of all of these; but it may be sufficient for the present purpose, to classify its parts as on the opposite page.

The differences in the construction of locomotives have produced different classes, and they have hence been classified in various ways, according to their use and the arrangement of their parts.

With reference to their *parts*, locomotives were formerly divided according to the *number of pairs of driving wheels* that they had; and this has been continued to the present time in the Baldwin Locomotive Works, where those having one pair of driving wheels are called B engines, two pairs C engines, and so on. Another system of classification has been according to the *position of their cylinders*, whether surrounded by the smoke-box or with outside connections, in which all locomotives were either *outside* or *inside connected* engines. The latter class has nearly disappeared from American engines, on account of their requiring the cranked axle, which was expensive; the working parts were also greatly crowded, and other injurious effects produced.

With reference to their *use* or *service*, we may now regard all American locomotives as of the outside cylinder pattern, and classify them as either *passenger*, *freight*, or *shifting*, which latter are often *tank* engines.

There is a sub-variety, which falls mostly under the first of these, called *narrow gauge* engines. Some of these are but a reproduction on a reduced scale of the larger engines. In the real type of narrow gauge engines the peculiarity is a short rigid wheel-base, or distance between the driving wheels. The peculiar construction which admits of this was designed by Mr. Robert Fairlie, in England, and greatly improved upon by Mr. William Mason, of Taunton, Mass. The cylinders, driving wheels, and all the working parts are attached to a frame, which turns about a centre-pin like an ordinary truck. The front part of the boiler is hung upon a vertical link, so that on passing short curves the truck and wheels very closely follow the curvature

CLASSIFICATION OF PARTS.

THE LOCOMOTIVE.

A. The BOILER, or apparatus for generating the power.

- I. *The Heating Apparatus.*
  1. The Cylindrical Shell.
  2. The Furnace.
  3. Miscellaneous.
- II. *The Feed Apparatus.*
  - *a.* The Pump.
  - *b.* The Injector.
- III. *The Safety Apparatus.*
  1. The Safety Valves.
  2. The Steam Gauge.
  - The Air Brake.
- IV. *The Transmission Apparatus.*
  1. The Throttle Valve.
  2. The Steam Pipe.
  3. The Exhaust Pipe.

B. The ENGINE, or apparatus for using and converting the power.

- I. *The Cylinder and Connections.*
  1. The Cylinder.
  2. The Cross-Head.
  3. The Connecting Rods
- II. *The Valve Gear.*
  1. The Slide Valve.
  2. The Link and Eccentrics.
  3. The Reversing Apparatus.
- III. *The Running Gear.*
  1. The Driving Wheels.
  2. The Axles and Journals.
  3. The Trucks.

The Framing.

The Tender.

The Tank and Bin.

The Brakes.

of the rails, while the boiler swings over, relatively to the truck, upon the link. These engines, so far as I know, are used almost exclusively for passenger conveyance.

In all engines of the passenger class, in which the maximum speed is wanted, and light loads carried in comparison with the freight, there is a necessity for a long wheel-base to prevent "galloping" or "pitching" of the engine, and in the narrow gauge engines this is effected by a rigid connection between the engine and tender, which, while it lengthens the total wheel-base by an amount equal to the distance between the rear driving wheel and rear tender wheel, does not at all effect their peculiar property of passing around curves of extremely short radius.

In the freight class, great tractive power, and therefore a multiplication of coupled wheels, a small diameter of driving wheels and a consequent low speed, are the distinctive features.

In the shifting class, the tank engines utilize the weight of the water and fuel by supporting it upon the driving wheels, and do not work under the disadvantage of pulling a heavy tender after them. The object is to move light loads for short distances and to start them and attain speed very quickly. They have a short wheel-base which enables them to run over switches and upon sidings of very sharp curvature, and this quality more than compensates for the pitching motion which would result if they were put upon fast passenger trains.

The cost of a modern American passenger locomotive is from $8,500 to $11,000. Its ordinary "life" is ten years. Sometimes an American engine will remain in operation twenty-five years, so great is the difference in the effects produced upon them in different localities, and under different conditions. According to a paper read before the British Association, the life of a locomotive is "thirty years;—boiler tubes, five years; crank axles, six years; tires, boiler and fire-box, seven to ten years; side-frames and axles, thirty years." "The total cost of repairs in that time is $24,450; so that it requires in eleven years a sum equal to its first cost," and the distance it would travel in that time may be taken at 220,000 miles.

The progress in the construction of steam engines has been in three directions,—*land*, or *stationary* steam engines, including the great diversity of examples in pumping engines for water works, and the portable and semi-portable types; *marine* and *locomotive*. Each

class has its distinctive features and conditions, in conformity with which the machine must be designed and under which it must work. In the locomotive, the speed, weight of train and the grade are given, from which to design and build the entire structure in all its intricate parts. The principles by which this is done have not yet, to any great extent, been reduced to formulæ, but the engines have been built by a process entirely empirical.

The locomotive is the result of an accumulation of a multitude of facts; in its development, as one new truth or fact after another became mentally established, practice reflected the added knowledge. It has hence been through a process of integration, with hardly an important change in theory since the time of Stephenson. The details, by the immense advance of the processes of manufacture, by the improvement of machine tools, have been minutely examined and improved until we have, seemingly, as perfect a practical exhibition of theory as we can hope to attain. The tendency of first inventions is complexity. Inventors seem to be often far more ingenious in making a machine that will do a diversity of operations, many of which may be superfluous to the object at hand, than in producing simplicity.

One of the first requisites of the production of power is economy. Every superfluous part added increases the cost, first, by the material wasted, the expense of machines made to produce it, the labor of fitting and skilled workmanship; and second, by the expense of looking after and repairing it, and the constant and greater part, if it is a moving piece, by the force consumed by friction in running.

Hence, in such a machine as we are considering, it might be supposed that as improvements were made simplification would follow, until the limit is reached when only the essential parts of the mechanism to fulfil the definite and specific object for which the machine is to be employed, remain. This does not seem to be the case, thus far, however, in the example before us, for from the outset we see that we have not to do with a perfect instrument. To quote from Professor Thurston, "the process of improvement has been primarily one of differentiation, the number of parts has been continually increased, while the work of each part has been simplified, a separate organ being appropriated to each process in the cycle of operations." The parts have increased, some in the moving mechanism, some for safety and signals, such as the Westinghouse air or the vacuum brake, the bell, whistle, etc., and others for convenience in manipulation.

In all improvement in design of the locomotive engine, then, existing examples have been taken as the basis and the proportions of a new one founded, with certain modifications according to the kind of service for which it is to be made, entirely upon estimates from the experience of the designer.

In our study of the locomotive engine, the subject falls apart into what are called theoretical and practical aspects. "Practice provides the facts; theory the inferences in regard to those facts."

There are hence two directions in which inquiries lie, in order to produce as perfect a machine as our present stage of development will allow;—first, the treatment of the scientific principles which are applied in the locomotive, which would be a subject for theoretical treatment; and second, the manner of constructing the machine in accordance with these principles. The latter is practice. I will take the former as the leading method of inquiry and determine what the practice is, as far as may be, especially in regard to the efficiency of the apparatus,—to trace what becomes of the power as it is transmitted from one piece of mechanism to another.

Assuming the foregoing statements as the text of my remarks, I have thought that the best mode of treating the subject was to select a good pattern of locomotive, which, having its parts and proportions already given, the reasons for these proportions could be studied and their conformity to theory, in so far as that has been applied to the locomotive, ascertained. For this purpose I have taken a first class bituminous coal-burning passenger engine for a rather heavy passenger service, and built at the Hinkley Locomotive Works, in Boston. This engine is of the four driving-wheel and leading truck pattern, was designed and built in the latter part of 1875 for the Eastern Railroad Company, and is now running on one of the fast Pullman trains of that road. It was selected both on this account and for convenience, and as being a fair type of the coal-burning engines running on the New England Roads.

To illustrate the parts of this engine, five drawings have been made, which show the details as follows:—

Plate A. Side elevation, plan and rear elevation of a Hinkley passenger locomotive. Scale, ½ inch to 1 foot.

Plate B. Details of locomotive;—cylinder, plan, longitudinal and cross section; piston, steam-chest, bed-plate, pump, cross-head, throttle, check-valve, etc. Scale, 1½ inches to 1 foot.

Plate C. Details;—Main connecting rod, slides, yoke, eccentric rods, equalizing beam, crank pins, boiler brace, levers, etc.

Plate D. Details;—Frame, quadrant and reversing apparatus, link, rocker and driving spring.

Plate E. Tender for the Hinkley Locomotive,—side elevation, plan and rear view.

These drawings were traced from a set made at the Hinkley Works and published in Weissenborn's "*American Locomotive Engineering*," and show nearly all the important parts.* The details and arrangement of parts are correct and will be often referred to, although the design is for a heavier engine than that we are considering, and hence some of the dimensions given are too large.

The following is a complete specification of this engine, obtained, with care taken in regard to its correctness, both from the specification in the books at the Hinkley Works, and from actual measurements of the parts.

Boston, Oct. 25, 1875.

General Description.—One eight-wheeled heavy engine and eight-wheeled tender for the Eastern Railroad Company. Name, none. Road number, 55. Shop number, 1225. Gauge of road, 4 feet $8\frac{1}{2}$ inches. Date of delivery, October 28th, 1875. To be a first class coal-burning passenger engine, having four driving-wheels coupled, a four-wheeled centre-bearing truck and eight-wheeled tender. All working parts thoroughly interchangeable, and all material warranted of the best quality.

DETAILS.

Engine.—*Cylinders*, of fine hard iron, placed horizontally, and bolted to frame and smoke-arch. Finish: lagged with wood and covered with brass; head of cast brass; steam chest trimmings of brass.

Diameter of Cylinders, 16 inches.

Length of Stroke, 24 inches.

Cylinder Cocks, worked with straight rod and lever in cab.

Oil Cups, cylinder oil cups on steam chests and gauge stand in cab with seamless brass tubes under lagging to steam chests.

Steam Ports: length, 14 inches; width, $1\frac{1}{4}$ inches.

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* The plates have been reduced to *one-half* their dimensions as drawn, and will be inserted, by permission, where referred to in the paper.

Exhaust Port: width, $2\frac{3}{8}$ inches.

Admission Ports: length, 14 inches; width, $1\frac{3}{4}$ inches. Offset face, $3\frac{1}{2}$ inches.

Exhaust Nozzle and tips, double; diameter, $3\frac{1}{4}$ inches.

Valves: Outside lap, $\frac{7}{8}$ inch; inside lap, $\frac{1}{32}$ inch; travel of valve, 5 inches.

Valve Motion: Links of hammered scrap iron, thoroughly case-hardened and made to cut off equally at all points of the stroke. Rockers and reverse shafts forged solid. Valve stems bushed with socket and key.

Rockers, of wrought iron; diameter of rocker shaft, $3\frac{1}{2}$ inches; arms, $9\frac{1}{2}$ inches long.

Links: 60 inches radius, 12 inches between centres; $13\frac{3}{4}$ inch lifters; pin, $\frac{3}{8}$ inch back.

Eccentrics, $13\frac{13}{16}$ inches diameter, 3 inches thick, 5 inch throw.

Piston Packing: Dunbar, two composition rings, babbitted. Iron cut into six pieces.

Piston Rods: diameter, $2\frac{5}{8}$ inches; length between shoulders, $34\frac{1}{8}$ inches.

Cross Heads of charcoal iron cast in dry sand, solid.

Slides: of steel; $45\frac{1}{4}$ inches long, 3 inches wide, $1\frac{1}{2}$ inches thick.

Yoke, of hammered iron, reaching from frame to frame.

Main Connecting Rods, length from centre to centre, 7 feet $4\frac{3}{8}$ inches.

Parallel Rods, length from centre to centre, 7 feet 6 inches.

Crank Pins: of steel; bearings, $3\frac{13}{16} \times 4$ inches, and $2\frac{13}{16} \times 2\frac{3}{4}$ inches.

Driving Wheels: Centres of cast iron, with hollow spokes, and rim. Diameter of centres, 57 inches.

Diameter of Driving Wheels, outside of tires, $62\frac{1}{2}$ inches.

Tires, of best Firthe's steel, imported, all flanged. Inside diameter of tire, 57 inches; width, $5\frac{3}{4}$ inches; thickness, $2\frac{3}{4}$ inches.

Driving Axles, of hammered iron; diameter of bearings, 7 inches.

Driving Boxes, regular. Length of journals, 7 inches; diameter, 7 inches.

Driving Springs, Nichols, Pickering and Co., Pittsburgh, 11 leaves.

Truck Wheels, N. Washburn's patent, with cast steel rims. Diameter of wheels, 28 inches.

Truck Journals: Length, 7 inches; diameter, $4\frac{1}{2}$ inches.

Truck Springs, N., P. and Co., 16 leaves.

Truck Frame, centre bearing. Frame of wrought iron, forged solid. Jaws of cast iron. Frame of $1\frac{1}{4}$ inch iron, $48\frac{7}{8}$ inches wide.

Frame, of hammered scrap iron, forged solid, with lugs to hold cylinders. End rails wrought iron; front rail, $3\frac{1}{2}$ inches deep, 3 inches wide; back rail $3\frac{1}{2}$ inches deep, 3 inches wide; offset 9 inches, 18 inch jaw.

Boiler.—Wagon top, 7 inch offset, of extra flange charcoal iron, thoroughly stayed and riveted throughout and having one dome over the fire-box. Throat sheets and all horizontal seams double riveted; fire-box thoroughly stayed to shell and dome; shell of boiler flanged up into dome; smoke-arch raised up even with lagging by one inch bar. Height of back end, 88 inches; height of door, $40\frac{1}{2}$ inches. Finish: boiler lagged with wood and covered with Russia iron, secured by finished brass bands.

Shell: Inside diameter 48 inches.

Thickness of Iron in Shell, $\frac{3}{8}$ inch.

Thickness of Iron in Front Tube Sheet, $\frac{1}{2}$ inch.

Tubes: of iron, 161 in number; length, 11 feet 0 inches; outside diameter, 2 inches; $\frac{5}{8}$ inch water spaces.

Fire-Box, of homogeneous cast steel, Bay State plate, 60 inches long, 66 inches high, and $35\frac{5}{8}$ inches wide inside.

Thickness of steel in *Sides* and *Back* of *Fire-Box*, $\frac{5}{16}$ inch.

Thickness of steel in *Tube Sheet*, $\frac{7}{16}$ inch.

Thickness of steel in *Crown Sheet*, $\frac{5}{16}$ inch.

Grate, coal-burning. Length, 60 inches; width, $35\frac{5}{8}$ inches; area of grate, 14·84 square feet.

Fire-Box Bracing: Centres of stay bolts not over 4 inches apart; centres of crown bars not over $4\frac{1}{2}$ inches apart.

Dome. One on furnace, of cast iron, lagged with wood, and covered with brass; diameter 28 inches.

Smoke Stack: for coal burning, of cast iron, 13 feet 8 inches high from rail; length $61\frac{1}{2}$ inches, with netting 38 inches in diameter.

Throttle Valve, 5 inches poppet.

Steam Pipes. Dry pipe, $5\frac{5}{8}$ inches inside diameter; branches of cast iron $4\frac{1}{2}$ inches in diameter.

Safety Valves, two in number, Richardson's patent, $2\frac{1}{4}$ inches in diameter, without levers.

Pumps. One right plunger pump, brass, with brass vacuum chamber. Valves of hard composition. Diameter of plunger $1\frac{7}{8}$ inches.

Injectors. One No. 6 Mack's; on left side, overrunning board and taking water back of cock.

Check Valves, of brass, covered with brass.

Whistle, 6 inches in diameter; worked by shaft and lever in cab.

Bell, large pattern; posts of iron.

Sand Box, with cast brass rings, covered with brass.

Cab, of black walnut; $63\frac{7}{8}$ inches long; well joint-bolted; roof covered with tin.

Pilot, of wood, vertical slats, well braced and ironed; iron broom stands.

Total Wheel Base, 21 feet $4\frac{1}{2}$ inches.

Rigid Wheel Base, 7 feet 6 inches.

Wheel Base of Truck, 5 feet 6 inches.

Weight of Engine, with water, about 63,000 pounds.

TENDER.—*Tank* of best tank iron, well braced. Thickness of iron in bottom and inside of legs, $\frac{1}{4}$ inch; in top and sides, $\frac{3}{16}$ inch; frame of wood; draw casting, Miller's new pattern.

Wheels, eight in number, Washburn Iron Co., of chilled iron, 30 inches in diameter; axles, E. R. R.

Springs, cast steel, elliptic; front tender, N., P. and Co.; rocker, 17 leaves; back tender, ditto.

Capacity of Tank, 2,500 gallons.

Weight of Tender, empty, 20,000 pounds.

Air Brake Pump, on left side, between wheels.

Painting: All unfinished work of engine and tender to be neatly painted and varnished; boiler to have a coat of mineral paint under lagging.

Sundries: Each engine to be furnished with steam gauge; gauge, heater, blow-off, and water cocks; also oil cans, two jack-screws, two pinch-bars, wrenches, hammers, file, boxes, etc.

The details and action of the locomotive, as far as I shall be able to enter upon their discussion, in accordance with the preceding classification, may be regarded in the following order:

A, *The Boiler.* I, *The Shell;* its construction, material, strength, and factor of safety. II, *The Heating Apparatus* and *Boiler Proportion.* III, *The Feed Apparatus.* IV, *The Safety Apparatus.* And V, *The Transmission Apparatus*, or the *Distribution of the Power* to the engine. B, *The Engine.* I, *The Cylinder* and its proportion. II, *The Valve Gear.* III, *The Action of Steam in the*

Cylinder and the *Theory of the Blast.* IV, *The Transmission of Power to the Wheels* by means of the piston, crank and connecting rods. V, *The Running Gear.* VI, *The Balancing of the Engine.* And VII, *Tractive Power and Train Resistances.*

There are, then, three principal steps in the inquiry; first, that of the transfer of the energy of heat to the steam, in which we consider the heating surface, rate of combustion, evaporative power and efficiency of the boiler; second, the subject of boiler pressure, since that is the form which the energy next takes, and which should be traced through all its losses till it gives its energy up to the piston; and third, that of the actual power rendered available at the circumference of the wheels, or the tractive power, the adhesion of the wheels to the rails, the resistances of the train, and the equivalent horse power developed.

I. The Boiler of a Locomotive Engine is usually defined to be "a close vessel in which steam is generated."* It has two principal functions. It must first retain the energy obtained in the form of pressure; and, second, produce it most economically. The first relates to boiler strength; the second to its efficiency. The first, it will be proved, is at a maximum when the form given to the material of which the boiler is composed is spherical. The latter, it will be seen, depends upon obtaining the maximum amount of heating surface. These two requirements are opposed to each other, one being at a minimum when the other is at its maximum. The resulting form of boilers for the generation of steam, modified in accordance with each of these two principles, has been the cylindrical.

The locomotive boiler has these distinct parts,—the cylindrical shell called the barrel, or boiler proper; the internal and external firebox attached to it; and the smoke box, upon which rests the chimney or smoke stack.

It is made up of several sheets of wrought iron, and in the internal fire-box, steel; of irregular shapes; bent to their proper form and riveted together by the system of single riveting, except in the longitudinal seams, which are double riveted. The names of these sheets or plates, referring to the position in the boiler which each occupies, are: the shell plates, off-set plates, side plates, bottom plate, front round head, front tube plate, back head, front furnace plate, crown sheet, dome plate, side plates, tube plate, ash pan, bottom and side plates, doors, and two smoke arch plates.

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* Wilson.

The boiler proper is a cylinder 11 feet long and 48 inches in inside diameter, and made up of three cylindrical sections. Each of these sections is formed from a single plate, 56 inches in breadth and 156½ inches long, which wraps entirely around the circumference of the boiler. The ends of each of these plates are riveted together with a .double row of diagonally placed rivets, and constitute a longitudinal seam in the boiler. The ends of the three sections which constitute the boiler shell, overlap one upon another, and are united by a single row of rivets around the circumference. In putting the sections together they shut one within another, not like the tubes of a telescope, but alternately over and under the edge of the section adjacent, so that the diameter of alternate sections is greater, by twice the thickness of the plate, than that of intervening ones.

Connecting the barrel of the boiler to the rectangular fire-box with its arched top are diagonal plates, shown in Plate A, at *a*, Fig. 1, four in number, called the off-set plates, which increase the radius of the outer shell at the fire-box end by 7 inches. The under plates are bent so as to form flanges upon which to rivet the vertical front side of the external fire-box.

The barrel of the boiler consists of the outer shell, which has at its extremities the two tube plates, placed 11 feet apart, and connected by 161 tubes, each 2 inches in diameter; the smoke-box, and the bracing. The smoke-box is simply an extension of the shell by an additional section, which forms a receptacle for the hot gases as they come in detached currents through the tubes from the fire box. The bracing consists of diagonal stays for the ends, angle iron, and ten longitudinal stay rods passing from the front tube sheet, through the steam space above the tubes to the back end of the boiler, and fastened by nuts and washers upon the outside. The boiler has lagging, which consists of felting and wood, covered with Russia iron, and held down by bands of brass running around the boiler.

The qualities which it is most desirable to obtain in the construction of the steam generators of locomotives, are: *adaptation* to the circumstances of their use;* *durability* or economy in the cost of repairs; *economy in construction*, in material and workmanship, by which weight would be reduced till limited by the other conditions; *strength*, to sustain both the internal pressure and other forces

* Trowbridge.

coming upon it; and, finally, *efficiency* or economy in evaporative qualities—to decrease the expense of maintenance, to produce more power without increase of weight, and to employ as thin heating surface and as great in extent as possible, without influencing in an injurious way the other conditions.

How nearly the locomotive boiler fulfils these conditions would form too large a subject for discussion here, and I will hence take up, in a general way, only the problems of boiler strength and efficiency.

The materials in use for locomotive boilers are wrought iron for the shell, and copper or steel for the fire-box. The advantages of copper are soundness, easy working, little corrosion or oxidation, ductility in working and flanging, and its superior conducting power to iron. Its disadvantages are its cost, softness, in resisting the abrading action of the particles of coal as they are driven against such parts as the crown sheet or tube plate, its loss of strength on being heated, and the greater thickness required for strength, which overbalances its superior conducting power. The unequal expansion, also, of two metals of so dissimilar a constitution as copper and iron, when used together, has an important influence.

Wrought iron has many advantages and but few defects, the greatest of which is its rusting. It is perfectly reliable, which cannot as yet be said of steel, for the unaccountable way in which that, apparently of the best quality, cracks in the fire-boxes when the boiler is cooling down, separating sometimes through the rivet holes, but often diagonally or between them, has formed a subject for almost endless discussion.

Experiments on Tensile Strength of Boiler Plate, made by C. B. Richards, Esq., M. E., Hartford, Conn.

Kind of Iron and its Brand.	Ultimate Tenacity—Tensile Strength per Square Inch, Original Cross Section.		
	Strongest Specimen. Lbs.	Weakest Specim'n Lbs.	Averages. Lbs.
Bay State Flange iron...........	52993	50770	52102
Bay State homogeneous metal (steel).........................	71139	70100	70672

Wrought iron increases in strength on heating, up to 570°,* and its properties, as well as those of steel, in respect to tensile strength,

* Experiments by Franklin Institute.

are best shown by the table inserted, which gives the facts concerning the metals that are used in the locomotive under consideration.

The iron and steel for this locomotive were furnished to the Hinkley Works on the authority of these experiments, and were not tested by them before being made up into the boiler. We may then safely take the ultimate tenacity of these two metals at the figures given in the column of averages.

(To be continued.)

THE MANCHESTER STEAM USERS' ASSOCIATION.

From *Scientific American Supplement*, New York, October 21, 1876.

At the request of the Judges, Group 20, of the American Exhibition, the Manchester Association sends the following particulars of the operation of their society :—

Offices : 9 Mount Street, Manchester, July 4, 1876.

THE CENTENNIAL COMMISSION, INTERNATIONAL EXHIBITION, PHILADELPHIA.

For the Use of the Judges in Group 20.

Gentlemen :—In reply to a letter received from Mr. Chas. T. Porter, requesting information as to the working of the Manchester Steam Users' Association, for the use of the Judges of the International Exhibition, Philadelphia, I beg to forward the following particulars, and in doing so will take up the points seriatim, in the order in which they occur in Mr. Porter's letter.

No. 1. "*Term of Existence.*"—The Association was established in the year 1854, and has been in active work ever since, increasing in the number of its boilers and the area of its operations.

No. 2. "*Average and Present Number of Boilers in charge.*"—The number of boilers now under inspection is as nearly as may be 3000. The average for the last five years has been 2500.

No. 3. *Character of the Boilers, and if of different types the number of each.*—By far the greater number of boilers enrolled with the Association are horizontal, and internally fired. Speaking approximately, the relative number of the various types is as follows :—

50 per cent. are what are termed "Lancashire" boilers; that is to say, having two internal tubes running through them from end to end, in which the fires are placed.

15 per cent. are of the "Cornish" Type; that is to say, having one furnace tube running through it from end to end, in which the fire is placed.

15 per cent. are externally fired, such as plain cylindrical, egg-ended colliery boilers; French or "Elephant," and "Butterly" boilers.

8 per cent. are variations of the "Lancashire" and "Cornish" boiler, with a number of small flue tubes, some termed multiflued, and others multitubular, etc.

6 per cent. are of the "Galloway" type.

6 per cent. are of miscellaneous types, such as boilers at iron-works heated by flames passing off from puddling and iron furnaces, water-pipe boilers, locomotive and marine boilers, and vertically internally fired boilers, etc. This proportion varies somewhat year by year, as boilers are changed.

No. 4. *Pressure carried—between what limits.*—All the "Lancashire" boilers made for members under the inspection of the Association, the ruling diameter of which is 7 feet in the shell, and 2 feet 9 inches in the furnace tubes, are fit for a working pressure, as a minimum, of 75 pounds on the square inch. Many are fit for a pressure of 85 pounds, others 90 pounds and 100 pounds. No new boilers are made to the Association's standard for a lower pressure than 75 pounds on the square inch. Many smaller boilers are carrying 120 pounds.

No. 5. *Character of the Examinations made, and their frequency.*—A complete examination of every boiler is made both inside and outside, when at rest and properly prepared, at least once a year, and more often if necessary: that is to say, if the boiler does not appear thoroughly sound or repairs have to be examined. Hydraulic tests are also had recourse to when necessary. In addition to the annual thorough examination, two "external" examinations are made of each boiler per annum, with the boilers at work and steam up. This number is a minimum.

No. 6. *Nature of the Defects and the Number of each per annum.*—The following is a list of the defects discovered, with the number of each for the year 1875:

Furnaces out of shape . . .	22;	3 dangerous.
Fractures	87;	10 "
Blistered plates	79;	6 "
Internal corrosion	163;	5 "
External corrosion	104;	21 "
Internal grooving	117;	1 "
External grooving	9;	2 "
Feed apparatus out of order . .	1	
Water-gauges " . .	7	
Blow-out apparatus " . .	14;	3 "
Fusible plugs " . .	6	
Safety valves " . .	30;	8 "
Pressure gauges " . .	110;	7 "
Boilers without glass water-gauges .	2	
" " safety valves . .	8;	1 "
" " pressure gauges .	6;	4 "
" " blow-out apparatus .	6	
" " feed back-pressure valves . . .	51	
Cases of over pressure . . .	9;	5 "
Cases of deficiency of water . .	2;	1 "

Total—defects, 833; 77 dangerous.

No. 7. "*Instructions given to Owners and Firemen.*"—We have no written code, but are thinking of preparing a list of instructions to firemen. All we ask from the owners is, to get a good boiler and a careful man. We impose no arbitrary conditions. Information to the owners is always accessible at these offices.

No. 8. *The Guarantee afforded to Members.*—The Association guarantees the members freedom from explosion, and the Association's guarantee has never failed. Its members continue to enjoy immunity from explosion year after year. As a pledge of good faith, the reports are endorsed with a pecuniary guarantee of £300, but the Association has no explosions. The only exception to this was the rending of a furnace through overheating in consequence of misuse by the owner, who charged the boiler heavily with caustic soda and arsenic, bringing down the incrustation but yet neglecting to blow out. No one was hurt, and the boiler was soon repaired and set to work again. We warn our members against using compositions and neglecting to blow out. We guarantee our members perfect immunity from explosion, provided only they meet us with ordinary fairness. Year after year we are able to report "*No explosion from any boiler guaranteed by the Association.*"

No. 9. *The Cost to Members of the Inspection and Guarantee.*—The charge for inspection is one guinea and a half per annum each boiler, within a radius of 40 miles of Manchester; beyond that distance according to arrangement. There is no charge for guarantee. The Association's guarantee is neither to be bought nor sold. If the Association considers a boiler unsafe, nothing will induce it to say it is safe. If the boiler is safe, there is no need to charge for saying so. The expenditure is incurred in inspection, and the Association has no explosions to make compensation for.

No. 10. "*The Result of the Work of the Association in Immunity from Accidents.*"—It is presumed that by the word "accidents" is meant explosions. Explosions in the great majority of cases are *not* accidental. They arise from known causes. Inspection is able to prevent their occurrence, and is found in the experience of the Association to be quite adequate. *See here reply to question No.* 8.

No. 11. *Upon what do you rely for Safety?*—Upon competent periodical inspection. *See reply to questions* 8 *and* 10.

No. 12. "*Low-water Detectors.*"—We recommend that each boiler should have two good glass water-gauges, fixed directly to the front end plate of the boiler, immediately under the eye of the attendant. We approve of a low-water safety valve which relieves the pressure of the steam as soon as the water falls below the desired level. Alarm whistles may be easily silenced, and, as a rule, have been discarded. A low-water safety valve is more reliable, as it blows off either for high steam or low water, and thus is kept in constant play.

No. 13. "*Automatic Feed Regulators.*"—We do not approve of these, thinking them apt to mislead, and to engender a false confidence. We prefer feeding by hand as more trustworthy.

No. 14. "*Testing Boilers in use by Hydrostatic Pressure.*"—We do not adopt this course as a rule, and only adopt it where there is some peculiarity in form, say to ascertain the strength of a flat surface, or when any question arises as to the power of a furnace to resist collapse. In the case of the cylindrical shells of boilers, we rely on careful inspection. If the plates appear to be wasted we drill them to ascertain the precise thickness, and sound the rivet heads to see if corrosion is interfering with the consistency of the metal. We have the boiler so set that all parts may be accessible to examination. If the brickwork interferes we have it removed. When hydraulic tests are applied, the boilers are gauged at the flat ends, and also in the furnace

tubes, to see if any movement occurs. We have no faith in "blind" hydraulic tests for getting at the strength of parts out of sight. Our rule is to see everything.

No. 15. "*The Experience and approved Usages of other Similar Associations in England.*"—The object of the Manchester Steam Users' Association is the saving of human life, and the prevention of explosions. It has no shareholders and pays no dividends. The President and members of the Executive committee give their time gratuitously year after year in the interest of the members and the public generally, with the object, as already stated, of saving life. There is no other similar association in the country, but there are joint-stock boiler insurance companies, founded for the purpose of dividend. I think I have now replied to all the inquiries contained in Mr. Porter's letter, but may add that our Association goes to the expense of sending a qualified officer to investigate every explosion that occurs in any part of the country, and draw up a full report, with illustrative drawings of the same. These are carefully preserved at the offices, and form most instructive and valuable documents. A very abridged statement of the description of boiler, course of the rents, effects of the explosion, and the cause, is given in a tabular synopsis published in the Association's printed monthly reports, circulated amongst the members, and sent to the press gratuitously, so as to disseminate the information as widely as possible.

The Association has boilers enrolled under its inspection situated in all parts of the United Kingdom. Also it has several corresponding members abroad, and is affiliated with another institution for the periodical inspection of boilers at Calcutta. Its monthly reports will be found in the library of the Franklin Institute at Philadelphia.

Trusting that this information will be of service to you, and wishing you every success in your labors,

I remain, Gentlemen, yours faithfully,

L. E. Fletcher, *Chief Engineer.*

St. Gothard Tunnel.—An international commission charged with the duty of reporting upon the St. Gothard Tunnel have officially remarked that, thanks to the improved machinery which has been introduced, the works have made great progress of late, so that, unless unforeseen obstacles should supervene, it will in future be comparatively easy to complete the tunnel at the average rate of 20 feet per day.—*Engineering.*

ON ROPE GEARING FOR THE TRANSMISSION OF LARGE POWER IN MILLS AND FACTORIES.*

By Mr. James Durie.

[A Paper read at the Meeting of the Institution of Mechanical Engineers, at Manchester, England, October 25, 1876.]

The best means of transmitting power from the prime mover to the various machines in a factory has long been a matter of importance to the engineer and to the manufacturer. Until lately, toothed gearing—either as spur or bevel wheels, or a combination of both—has been almost universally employed for first motions, the smaller powers being taken off pulleys by leather belts. The facility of taking small powers off drums to machines by means of belts, and the absence of noise and vibration, led to the adoption, in the United States of America, of broad leather belts for the transmission of large powers from the prime mover to the shafting in factories; and the success which has followed the adoption of these large belts there, has led to their being adopted by many users of power in this country.

The object of the present paper is to bring before the institution the plan of transmitting large powers by means of round ropes working on grooved wheels, which, in some parts of this country, has been largely adopted as a substitute for toothed gearing. The experience gained by the firm with which the writer is connected, in this mode of transmitting power, has extended over a period of thirteen years; and wherever it has been employed, either to replace toothed gearing in old or for new works, it has always given complete satisfaction.

In this mode of driving, the fly-wheel of the engine is made considerably broader than the fly-wheel of an engine having cogs on its circumference; and, instead of cogs, a number of parallel grooves for the ropes are turned out, the number and size of which are regulated by the power to be taken off the fly-wheel. The power which each of the ropes will transmit depends upon their size, and the velocity of the periphery of the fly-wheel. The ropes employed are of two sizes for large powers, namely, $5\frac{1}{4}$ inches and $6\frac{1}{2}$ inches circumference; another size of rope, $4\frac{1}{4}$ inches circumference, is employed for small

* From *Iron*, London, Oct. 28, 1876.

powers, but there is no definitely ascertained limit to the size of ropes that may be employed. Where large powers are required, and where large pulleys can be used, it is best to use heavy ropes, and the contrary when the opposite is the case.

The velocity of the periphery of the grooved fly-wheel and pulleys is generally arranged to be between 3,000 and 6,000 feet per minute; and the velocity being settled and the power of the steam engine known, the number of the ropes required to transmit the power is then determined, from the experience that has been gained of the amount of power transmitted by ropes in previous cases. It is very essential that the right proportion between the diameter of the ropes and the pulleys is obtained; if the diameter of the pulley is too small, the rope in continually bending over them is apt to strain the strands and grind the core into dust, and on the size of the pulley in a great measure depends the life of the rope. As a general rule the circumference of a pulley should not be less than thirty times that of the rope which works on it. In apportioning the distance between the driver and the driven shafts, great latitude may be taken —a distance of from 20 to 60 feet may be taken as a fair space.

The mode of applying a complete system of rope gearing may be seen at a factory for spinning and weaving jute belonging to Messrs. A. and J. Nicoll, at Dundee, and fitted up by Messrs. Pearce Bros., Lilybank Foundry, of that town; this gearing has been working from June, 1870. The engine fly-wheel is 22 feet diameter, and has eighteen groves cut in its circumference; its width is 4 feet 10 in. over all. The engine makes 43 revolutions per minute, and the velocity of the periphery of the fly-wheel is 2,967 feet per minute. The power of the engine varies from 400 to 425 ind. h. p.; the power transmitted by each of the ropes, which are 6½ inches circumference, is, therefore, about 23 h. p. The power is transmitted to the ground floor by five ropes on to a pulley 7 feet 6 inches diameter, the power required being 115 ind. h. p.; that to the first floor by four ropes to a pulley 5 feet 6 inches diameter, the power required being 92 ind. h. p.; and that to the attic by six ropes on to a pulley 5 feet 6 inches diameter, the power required being 138 ind. h. p.; two shafts being required in this room, the power to the second shaft is transmitted by horizontal ropes, whilst on the other side of the engine shaft three ropes transmit 69 ind. h. p. to a weaving shed, the pulley being 7 feet 6 inches diameter. The ropes should never

be so heavily loaded as to draw them, even on short spans, to a near approach to a straight line; in this factory each rope, traveling at a velocity of 2,967 feet per minute, transmits, as above, 23 ind. h. p., the tension on the rope is, therefore, $\frac{33{,}000 \times 23}{2{,}967} = 256$ lbs., which is a very long way under the breaking strength of the ropes.

The ropes do not rest on the bottom of the groove, but on its V-shaped sides; these sides are generally made at an angle of about 43° to each other. If the angle at which the grooves are formed is very obtuse, the ropes will slip; if too acute, much friction may be caused by the rope becoming wedged into the groove. As the sum of the tensions upon the two parts of a band is the same, whatever be the pressure under which the band is drawn or the resistance overcome, the returning side of the rope is as much slackened as the working side is tightened. It is therefore generally advisable, when it can be so arranged, to have the tight or driving side of the ropes at the bottom, so that the returning side may lap round the top of the pulleys, and consequently obtain extra bearing surface; when the opposite is the case, the ropes fall sooner out of the grooves, and so lessen the bearing surface. It is not always practicable to arrange this, and in the case of taking the power off both sides of the driving pulley, it is obviously impossible.

None of the shafts of this factory are driven from the fly-wheel by less than three ropes, the strain on each rope being only, as shown above, 256 lbs.; it may therefore be supposed that a greater weight may temporarily be put upon a rope, in case any of the ropes should require to be tightened up, and this is often done. A rope is taken off at a meal hour, respliced, and put on again at the next stoppage of the engine, thus avoiding any necessity for night work or overtime. Night work should always be avoided, for besides the extra expense incurred, the work is never so well done by artificial light as it is done by daylight.

In the Samnuggur Jute Factory, Calcutta, which is a one-story building, all the machinery, both spinning and weaving, is on the ground floor. The engines are placed near the middle of the building; they are about 1,000 ind. h. p., and make forty-three revolutions per minute; the fly-wheel is 28 feet diameter, and its width 6 feet 7 inches; the velocity of the periphery being 3,784 feet per minute. The ropes are $6\frac{1}{2}$ inches circumference, eighteen ropes transmit the

power to the right hand or spinning side, and seven ropes to the left hand or weaving side, making a total of twenty-five ropes; each rope therefore transmits 40 ind. h. p. The tension on each rope due to this load at the above velocity is $\frac{33,000 \times 40}{3,784} = 349$ lbs., which is rather a heavier load than in the previously described factory; all the shafts are also driven by more than one rope, with the exception of some of the line shafts in the weaving shed. Rope gearing was only adopted in this case after the most searching inquiry as to its suitability for working in the warm and humid climate of Calcutta, and its adoption has been attended with very satisfactory results, both in this case and also at the Sealdah Mills in Calcutta.

The drawings show the arrangements adopted when the factories have been specially designed for rope gearing, but this gearing has often been applied to replace toothed gearing in mills already built. The plan then adopted is to put in a new grooved fly wheel, or to place grooved segments upon the existing fly wheel, when the speed is sufficiently great to allow of a limited number of ropes being employed, and the width of the wheel pit is also sufficient for the purpose; but if this plan cannot be adopted, grooved pulleys are put on the second-motion shaft, and the ropes carried to the different stories of the mill. It has even sometimes been necessary to put in a counter shaft, so as to gain speed and get sufficient length between the centres of the shafts on which the pulleys are placed.

A comparison has now to be made between the system of rope gearing and the other two systems in use at the present time. The system in most general use is toothed gearing; in this the first driver is the spur wheel fitted on to the crank shaft of the engine, into which is geared the driven pinion of smaller size. In order to insure these two wheels working well it is absolutely essential that the centres of the engine shaft and the shaft of the pinion are rigidly fixed at the correct distance from each other, and that the teeth of the two wheels are accurately of the same pitch and size. The first of these objects is obtained by making the engine bed, in a horizontal engine, a strong rigid casting resting on an expensive ashlar foundation, or in a beam engine the foundations are alone depended upon. If these objects are obtained, the wheels ought to work smoothly and without much noise; but how often this desirable object is obtained, it only requires a walk to be taken through the streets of a

manufacturing town, to ascertain by the rumbling noise, sometimes heard at a distance of several hundred yards, that all is not as it should be for the safe and economical transmission of the power of the steam engine. If the factory consists of more than one story, the power has to be taken from the second-motion shaft, by means of an upright shaft and bevel wheels, requiring heavy wall boxes, and strong walls to keep the wall boxes in their places; the whole object in the construction of the factory being to secure a rigid and immovable structure, a matter which is very difficult to attain.

In the case of rope-gearing, the ropes by which the power is transmitted consist of an elastic substance, and their lightness, elasticity, and comparative slackness between the pulleys, are highly conducive to their taking up any irregularity that may occur in the motive power. This accounts for the slight attachments that are required for shafting driven by ropes from a grooved fly wheel; and it is the same with all the bearings throughout the mill, the shafts in the various flats only requiring a light wall box, bracket, or the bearing may be carried on a column of the mill. The cost of fitting up a mill with rope gearing is considerably less than with tooth gearing, when the shafts to be driven revolve at a high speed, but the cost is about the same in other cases. It is, however, rather difficult to give exact figures for this comparison, one great saving being in the foundations of the engine, the wall boxes, and the extra strength of the walls required for upright shafts.

The great advantage of rope gearing, however, is the entire freedom from any risk of a breakdown; when a rope shows symptoms of giving way—and ropes always give symptoms of weakness long before they break—the weak rope can be removed and another put in its place at any meal hour or evening. The cost of the maintenance of ropes for transmitting 400 ind. h. p. has been found to be £20 per annum, or about £5 per 100 ind. h. p. per annum. This is made up of the cost of renewal of the ropes, and occasional wages for tightening them. Some ropes have been found to run ten and a half years, but as the general rule, the life of a rope may be said to be from three to five years, though even five years has been often much exceeded.

The friction of rope gearing has often been found to be, for high speeds, considerably less than that of toothed gearing; but the writer regrets not being able to give definite information on this point, which is a very important one to those contemplating altering

their gearing or building new works. The reason why no definite reason can be given—beyond the universal impression of those who have adopted them, that ropes require less power to drive than toothed gearing—is, that in all cases where rope gearing has been substituted, other alterations have been made at the same time, or the engines were, after the alteration, driven at an extra speed of ten or fifteen revolutions per minute. However, every one who has substituted rope gearing for toothed gearing, also agrees in bearing testimony to the great improvement and steadiness of driving obtained after the alteration, and that they are enabled to turn off a greater amount of yarns from the machinery in the same time. The tendency at the present time, with the introduction of shorter hours of labor and foreign competition, being to increase the speed of shafting and machinery, to be able by this means to increase the speed of the shafts must be of great advantage to those who own old mills, the toothed gearing of which is generally driven as fast as it is safe to drive it.

The ropes used for rope gearing are mostly made of hemp, carefully selected; the qualification of a good rope being that the fibres are as long as possible, and that the rope should be well twisted and laid, and yet be soft and elastic. It is also very important that the ends of the ropes should be united by a uniform splice—the splice should not be of a greater diameter than the other part of the rope; to effect this object the splice is made about nine or ten feet long.

The comparison between rope gearing and toothed gearing having been made, it remains to compare ropes and leather belts, which latter have been largely used in the manufacturing districts of Lancashire and Yorkshire, for the transmission of large powers. The writer has not been able to obtain very satisfactory information as to the amount of power absorbed in friction by large belts; in some cases it has been said to be more, and in some less, than with toothed gearing. The most trustworthy information he has obtained is in the case of a four story woolen mill, where an upright shaft, with bevel gearing, was replaced by two belts, one 22 inches wide, and the other 27 inches wide, the power transmitted being 400 ind. h. p., and the speed of the belts 3,000 feet per minute. The driving pulleys are on the second-motion shaft. In this case the power is stated to be the same with the belts as it was before the alteration; but, as in the case of rope-driving, the "turning" is found to be much superior to what it was before the alteration. The width of the pulleys for

ropes is generally rather less than for belts transmitting the same power; but there is some difference of practice as to the width of belt used for transmitting a certain power. The cost of hemp ropes is considerably less than of leather belting, the cost of hemp ropes being about 1*s.* per pound against 3*s.* per pound for leather belts. The grooved pulleys for ropes cost more than plain pulleys, but making allowance for this, the total cost of ropes and grooved pulleys for transmitting a given power, does not exceed one-half or two-thirds the cost of leather belting and flat pulleys. The advantage of ropes over belting, however, lies in the power being divided up into a number of ropes, so that in the case of any one of the ropes showing symptoms of weakness, that rope may be removed by stopping the engine for a few minutes, the remaining ropes continuing to do the work until a stoppage of the engine occurs. In the case of belting, as only one belt is employed to drive one flat of a mill, if anything were to occur to the belt, the whole of that flat would be stopped until the belt was repaired.

Judging from the practice adopted, the comparative amount of power transmitted by certain sizes of ropes and widths of double belts, the writer finds that a $6\frac{1}{2}$ inch circumference rope does about the same amount of work at a given speed of say 3,000 feet per minute as a belt 4 inches broad. This width, however, represents the smallest width adopted as a rule, 5 inches corresponding to the American practice, but taking a 4 inch belt, the bearing surface of a $6\frac{1}{2}$ inch circumference rope on the sides of the grooves on a 4 feet 6 inch pulley will be half the circumference, or 85 inches, and allowing the rope half an inch width of bearing on each side, or 1 inch for both sides, the total bearing surface is $85 \times 1 = 85$ square inches, whilst the belt has $85 \times 4 = 340$ square inches, or four times the amount. Consequently, in order that a $6\frac{1}{2}$ inch circumference rope may transmit as much power at the same tension as a 4 inch belt, the effective pressure per square inch of the bearing surface of the rope on the pulley must be at least four times as great as that of the belt.

In order to obtain some information bearing on this point, a set of experiments have been made by Mr. A. W. Pearce, at Lilybank Foundry, Dundee, the results of which are given in the following table. The experiments were made with the materials at hand; both the pulleys were just as they came from the lathe, and equally smooth, and they were nearly the same size as named in the table. Comparing together Nos. 2 and 5 experiments, it is seen

that a 6 inch circumference ungreased rope, with 336 lbs. suspended at one end, and passing over a 4 feet 9 inch grooved pulley which was at rest, required only 28 lbs. at the other end to prevent slipping; whilst a half-worn good single leather belt, 4 inches wide, with the same weight at one end, and passing over a 4 feet 6 inch pulley, required 113 lbs. at the other end to prevent slipping, or about four times as much as with the rope. The bearing surface of the rope would be only about one-fourth that of the belt, and the effective pressure per square inch of the bearing surface of the rope was consequently in this case sixteen times as great as that of the belt. In the experiment No. 4 a double leather belt, 6 inches wide and $\frac{3}{8}$ inch thick, with the same weight at one end, and passing over a 4 feet 6 inch pulley, required 98 lbs. at the other end to prevent slipping, or $3\frac{1}{2}$ times as much as with the 6 inch circumference rope. The experiments show, however, such a great difference between the results with different sizes of ropes as to make it impossible to come to any definite proportion between the friction of ropes and belts; but they show, as was to have been expected, that ropes have a considerably greater hold on the V-shaped grooves per square inch of bearing surface than flat belts have on pulleys.

Experiments on the Friction of Ropes and Leather Belts on Cast Iron Turned Pulleys.

No. of Experiment.	Rope or Belt	Circumference of rope or width of belt.	Diameter of pulley.	Load suspended at one end.	Weight required at other end to prevent slipping. Ungreased.	Greased.	Remarks.
		Inch.	Ft. In.	lbs.	lbs.	lbs.	
1	Rope.	7	4 9	336	56	102	Rope somewhat worn.
2	"	6	4 9	336	28	90	Rope new.
3	"	$5\frac{1}{4}$	4 9	336	14	..	Rope new.
4	Belt.	6	4 6	336	98	133	Double belt $\frac{3}{8}$ in. thick.
5	"	4	4 6	336	113	..	Single belt half worn.

Note.—The rope pulley used in these experiments was grooved for $6\frac{1}{2}$ inch circumference of rope.

The writer has been informed that in the United States several rolling mills are driven by means of flat leather belts, and that very satisfactory results are obtained by their use, and he wishes to draw the attention of members engaged in this department of manufacture to the suitability of rope gearing for this purpose. Although he is not aware of any practical example of its having been applied to driving rolling mills, he is confident that from the slackness with

which the ropes can work, and the hold they have on the grooves of the pulleys, they would be admirably adapted for taking up the shock which is thrown upon the gearing of a train of rolls when the iron enters the rolls.

Mr. Welsh opened the discussion by a mathematical criticism of the principles involved in the paper, arriving at a corroboration of the angle of 40°, approved by Mr. Durie, on the ground that the tangent of half this angle (0·364) ought to be equal to the coefficient of friction, which, taking the mean of the writer's experiments, was 0·399. He enforced his remarks by symbols and formulæ of fearful complexity, inscribed upon the blackboard.

Mr. Paget said that he had been working in the same direction, and had performed over 900 experiments with a view of getting at some general principle. The results, however, were so absurdly discordant that he had abandoned the task. His best results corroborated Mr. Durie's angle of 40°.

THE DURATION OF A BLOW.

[From *Engineering* London, Oc. 27, 1876.]

In a recent number of *Engineering* (*vide* page 330 *ante*), a paper was reprinted,* describing an ingenious method by which very small intervals of time occurring between two successive mechanical movements may be determined with a considerable degree of accuracy. For the determination of the velocities of projectiles this method, which has been devised by Mr. Robert Sabine, would probably not be so applicable as the ordinary chronoscope systems, unless the time interval to be determined were less than the $\frac{1}{1000}$ of a second, when it would become superior, from the fact that electricity having no appreciable inertia there is no limit to the smallness of the interval, which may be measured by means of its outflow from an accumulator. But for the determination of the duration of contact between metallic surfaces during a blow it is the only system which can afford us any information at all. For this reason the following series of experiments, with the details of which we have been favored by Mr. Sabine, will be regarded with much interest.

These experiments, which were intended as preliminary to a more extended inquiry, were made with a view to find approximately how the duration of a blow varied with the weight of the hammer, its

* *Philosophical Magazine*, May, 1876.

velocity of descent, and with the materials. An iron ball, weighing $\frac{1}{4}$ lb., was suspended by a fine wire from an insulated support upon the ceiling, so that when it hung vertically it just grazed the vertical face of an ordinary blacksmith's anvil placed upon its side on a table. By raising the ball and letting it swing against the face of the anvil a blow of varying force could be struck. On rebounding, the ball was arrested whilst the excursion of the galvanometer needle was observed. By measuring the angle through which the ball was separated, its vertical fall and final velocity could be easily deduced. In this way the greatest vertical height from which the iron ball was let fall on to the face of the iron anvil was 4 ft., the least about $\frac{1}{80}$ inch. Six readings were taken for each height, and they were invariably found to agree amongst each other. The means only are given in the following records:

Vertical Fall in Inches.	Duration of Contact in Seconds.
48	0·00008
36	0·00008
28	0·00008
17	0·00009
$9\frac{1}{4}$	0·00010
4	0·00011
1	0·00013
$0\frac{1}{4}$	0·00016
$0\frac{1}{16}$	0·00018
$0\frac{1}{32}$	0·00021
$0\frac{1}{80}$	0·00030

From this it would appear that when the velocity of a blow is increased, the duration is decreased within a certain limit: but that it reaches a minimum. The velocity of impact in the first experiment was about sixty times as great as in the last one; but the duration of the blow appears to be reduced only to about one-fourth of the time. The blows given by two hammers of different weights were compared. No. 1 weighed 4 oz., No. 2 weighed only $2\frac{1}{4}$ oz. The durations of the blows were as follows:

Vertical Fall.	Duration of Contact.	
	Ball No. 1.	Ball No. 2.
in.	seconds.	seconds.
1	0·000135	0·000098
4	0·000096	0·000083

It appears from this that a heavier hammer of the same material gives a longer duration of blow.

In the course of these experiments it was observed that the ball after striking the anvil rebounded irregularly, sometimes to a greater, at others to a less height, and that some relation appeared to exist between the heights to which the ball rebounded and the excursions of the galvanometer needle due to the residue of the charge.

In the next series, therefore, the rebounds of the iron ball from the iron anvil were measured and recorded, from which it appeared that when the rebound was greater the duration of contact was shorter, and *vice versa*.

Vertical Fall.	Vertical Rebound.	Duration of Blow.
in.	in.	seconds.
6	2	0·000120
6	$2\frac{1}{2}$	0·000111
6	$3\frac{1}{4}$	0·000101
6	$3\frac{1}{2}$	0·000091
$14\frac{1}{2}$	$3\frac{1}{4}$	0·000106
$14\frac{1}{2}$	$4\frac{1}{2}$	0·000103
$14\frac{1}{2}$	$5\frac{1}{4}$	0·000095
$14\frac{1}{2}$	$6\frac{1}{2}$	0·000086
25	$7\frac{3}{4}$	0·000096
25	$8\frac{1}{4}$	0·000091
25	$9\frac{1}{2}$	0·000086
25	12	0·000078

The explanation of this is probably that when the energy of the blow is expended in bruising or permanently altering the form of the hammer or anvil by which the contact of the two is prolonged, it has less energy left to enable it to rebound, and *vice versa*. Substituting a brass anvil and brass ball, it was found that the blow was duller, the rebound much less, and the duration of contact nearly three times as great as when an iron ball and anvil were used.

Vertical Fall.	Vertical Rebound.	Duration of Contact.
in.	in.	seconds.
$1\frac{3}{4}$	$0\frac{1}{3}$	0·00036
6	1	0·00033
$14\frac{1}{2}$	$1\frac{1}{2}$	0·00026
25	2	0·00027

This series shows also the longer duration of the blow when its velocity is small. Using a brass anvil and iron ball the duration of the blow was greater than when both were of iron, but less when both were of brass.

Vertical Fall.	Vertical Rebound.	Duration of Contact.
in.	in.	seconds.
$1\frac{3}{4}$	$0\frac{1}{8}$	0·00021
6	$0\frac{1}{2}$	0·00018
$14\frac{1}{2}$	$1\frac{1}{3}$	0·00015
25	2	0·00014

Striking the brass anvil with a common hammer, the duration of the blow appeared shorter when struck sharply.

	Duration of Contact.
	seconds.
Moderate blow, .	0·00027
Harder blow, . .	0·00019

Striking the blacksmith's anvil with a common carpenter's hammer, the duration appeared to be nearly constant:

	Duration of Contact.
	seconds.
Moderate blow, ...	0·00011
Harder blow, ...	0·00010

It was, of course, necessary to allow in each case the hammer to rebound freely, and not to prevent it doing so by continuing to exert any pressure at the instant of the blow. When this condition was observed, in was invariably found that the harder and sharper the blow the shorter was its duration. It was also noticed that whenever the anvil gave out a sharp ringing sound, the duration of the blow was much shorter than when the sound was dull.

A very slight error would be introduced by reason of thermo-currents set up between the metals at the moment of the blow. By reversing the direction of charge of the accumulator, however, the effect from this cause was found to be quite inappreciable. Mr. Sabine's experiments are, as we have said, altogether very interesting, and we hope hereafter to be able to record the results of his further researches.

Purification of Bisulphide of Carbon.—M. L. H. Friedburg.—The author distils the sulphide over a pure vegetable fat, such as palm oil. To free the sulphide of carbon from a little fatty matter which it carries over, it is poured into fuming nitric acid, stirred, and allowed to digest for twenty-four hours. It is then mixed with cold water, distilled at 50° or 60°, mixed with water again, and re-distilled, when it is obtained perfectly pure.—*Berichte der Deutschen Chemischen Gesellschaft zu Berlin.*

Errata.—For Article on the Strength of Thick Hollow Cylinders.

Correct page 330, line 21, for Dividing by dr, read Dividing by $r\,dr$.

Correct page 331, line 3 (from bottom), for

$$= \alpha - \beta\left(\frac{du}{dr} - \frac{u}{r}\right), \text{ read } (\alpha - \beta)\ \left(\frac{du}{dr} - \frac{u}{r}\right).$$

Correct page 332, line 6, for

$$\text{or to } \frac{d\left(\frac{u}{r}\right)}{dr}; \text{ read or } \tfrac{1}{2}\frac{du}{dr} - \frac{u}{r^2} = \frac{d\left(\frac{u}{r}\right)}{dr};$$

Correct page 332, line 13, for

$$\text{to } \frac{d\,(r\,u)}{dr}; \text{ read } r\,\frac{du}{dr} + u = \frac{d\,(r\,u)}{dr};$$

Chemistry, Physics, Technology, etc.

INFUSORIAL EARTH AND ITS USES.

By Dr. W. H. Wahl.*

[From the *Quarterly Journal of Science*, for July, 1876.]

Geologists have long since established, beyond peradventure, the fact that there are rocks in the interior of continents, at various depths in the earth, and at great heights above the sea, which are almost entirely made up of the remains of what were once living organisms. Such rock-masses, says Lyell, may be compared with modern oyster beds and coral reefs, and, like them, their rate of increase must have been extremely gradual. But there are a variety of mineral deposits that are now proved to have been derived from plants and animals, of which the organic origin was not suspected even by naturalists. Great surprise was therefore manifested when the late Prof. Ehrenberg announced the discovery that a certain kind of siliceous stone, called tripoli, was entirely composed of the remains of countless millions of extremely minute organic beings. This observation of the famous German microscopist speedily led to the discovery of the fact that deposits of this character were quite abundant, and that they were even being formed at the present time over extended areas. The minute organisms, whose skeletons make up the bulk of the deposits, which are now known under the name of infusorial earth, have been shown to inhabit the ocean in inconceivable numbers, giving rise to the luminosity of the waters, which has been the subject of much discussion, and flourishing in almost every place where water stands for several months of the year. Their indestructible shells are therefore to be found in greater or less quantity in the sedimentary deposits of all our bogs, ponds, and slow streams. They are found in great abundance beneath peat bogs, where they constitute strata, often many feet in thickness and of great extent, almost entirely composed of the siliceous carapaces of

* Editor *Polytechnic Review*, Phila.

organic beings, so inconceivably minute that millions of their remains are found in a single inch. Ehrenberg estimates that about 18,000 cubic feet of these siliceous organisms accumulate annually in the harbor of Wismar, in the Baltic. He has, furthermore, demonstrated that they accumulate in the beds of American and other seas, lakes and rivers.

The deep sea soundings which have lately been conducted in various quarters of the world, and have attracted much popular interest, have shown, likewise, that the impalpable mud or ooze, which is accumulating at great depth in the bed of the Atlantic and other oceans, is made up almost entirely of the mineral skeletons of certain extremely minute organisms. Of these shells, some are calcareous, and appear to be identical with the organisms which abound in the chalk of Europe—the chalk, indeed, is largely made up of such organic remains—while others are siliceous. One of these deposits in the North Atlantic has been traced over a distance of thirteen hundred miles in breadth, and not less than six hundred miles in length.

In peat bogs, swamps, and the like, both of modern and ancient origin, there are often found layers, at times many feet in thickness, and of considerable extent, of a white siliceous paste, which is found beneath the microscope to be made up wholly of the remains of these minute organisms. These deposits, with which this article is chiefly concerned, are designated by geologists with the name of infusorial earth. The substance of which they are composed has generally, when dry, the appearance and consistence of friable chalk, and the remains of which it is made up, and which were formerly referred to microscopic infusoria, are now generally held to be plants, called by naturalists *diatomaceæ.* The remains of these diatomaceæ are of pure silex, and their shapes, as seen beneath the microscope, are various, and form objects, often of extreme beauty. These forms are very marked and constant in particular genera and species, of which many hundreds have been described and classified by Ehrenberg, Bailey, and others, and while many of the fossil forms are identical with living species, others are allied to them; and the so-called infusorial beds are sometimes of marine and sometimes of fresh water origin. The infusorial earth may readily be distinguished from the several calcareous and clayey deposits which it resembles in appearance, by the fact that it does not effervesce in acids, and its ready solubility

in solution of caustic soda or potash. It has long been well known in the arts as a powder for polishing stones and metals. At Bilin, in Bohemia, which is famous for its occurrence, there is a single stratum of this material, not less in some places than 18 feet in thickness, and extending over a large area. This stone, when seen beneath the microscope, is found to consist of the siliceous plates or frustules of the above mentioned diatomaceæ, united together without visible cement, and so inconceivably minute are the particles of which it is composed that, according to Ehrenberg's statement, a single cubic inch, which weighs about 220 grains, contains about 41,000,000,000 of individuals, and a single grain no less than 187,000,000. Other deposits of infusorial earth (kieselguhr), scarcely less extensive, occur in Germany, at Berlin, and at Planitz, in Saxony. It is found near Lüneburg, in a stratum nearly 28 feet in thickness, and again at Kliecken, near Dessau, and in the vicinity of Cassel. In England deposits of considerable magnitude have been found in Surrey, at the base of the chalk hills, and elsewhere. In Ireland there is a celebrated stratum on the banks of the River Bann, in the county of Down, and which, from being in much request for polishing plate, is locally known as Lord Roden's plate powder; another bed is found at the base of the Mourne Mountains, in the same county. In Lapland a similar earth is met with, which in times of scarcity, it is said, is mixed by the inhabitants with the ground bark of trees and used for food. The edible earth of Lillhaggsjon, in Sweden, is of the same nature. The infusorial earth is found in quantity in the Isle of France and at San Fiora, in Tuscany, and deposits of various thicknesses have been detected in Africa (the tripoli of commerce is an infusorial earth that has long been exported from the country whose name it bears), Asia, Australia, and New Zealand. In America it has been found in a great number of localities, and occasionally in enormous quantities. Of this nature are the beds of white earth along the banks of the Amazon, in Brazil, and used occasionally as food (?) by the native inhabitants. They have been detected also in Newfoundland and Labrador. In the United States perhaps the most remarkable deposit is that upon which the City of Richmond, Va., is built; this deposit is, in places, over 20 feet in thickness, and has been traced by Prof. W. B. Rogers, who was the first to point out its nature, from Herring's Bay, on the Chesapeake, Md., to Petersburg, Va.,

and beyond. At Petersburg the stratum is 30 feet in thickness. Beds of the same character and of some magnitude have likewise been found in California, Oregon, and other points on the Pacific, and at West Point, N.Y.; while of less importance are the infusorial beds at Wrentham and Andover, Mass., Smithfield, R.I., Stratford, Conn., and other localities too numerous to mention.

An interesting occurrence of this nature is the deposit of infusorial earth at Drakeville, Morris County, New Jersey, and which, through the instrumentality of the writer and others, was first brought into general public notice about three years ago. The bed in question is on the property of the late Frederick S. Cook, and is located at the foot of Schooley's Mountain. The annual report of Prof. George H. Cook, State Geologist of New Jersey for 1874, contained a descriptive article in reference thereto, from which we obtain the following statements concerning its probable extent, etc.:

"It has been known as a white earth or marl for a long time, and some years since was dug out and spread upon the soil as a manure; it had also been observed to possess remarkable excellence for scouring silver. The establishment of a manufactory for making nitro-glycerine and giant powder at McCainsville, near Drakeville, in which infusorial earth imported from Germany was used, led to an examination of this deposit, when it was found to be the same material with that they were bringing from Europe. The deposit occurs in a depression of the surface just at the foot of the mountain (Schooley's). The swale appears to be occupied in its lowest part by a common swamp of low bushes, growing in wet black earth; but by digging in the black earth it is found to be only about a foot thick, and underneath it is the infusorial earth. The extent of the black ground is about 540 feet in length by 200 feet in breadth, and 100 yards north-east is another but much smaller deposit. A trial pit sunk in the middle of the swale showed a thickness of 12 inches of black earth, 8 inches of very light infusorial earth, and 12 inches or more of a much denser infusorial earth. The lower part is said to be 3 feet thick, but I only examined the upper foot of it."

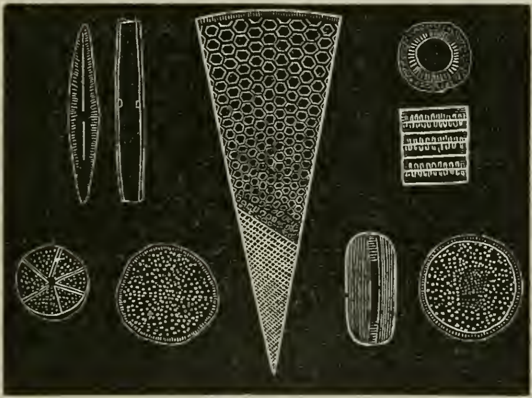
The report continues: "There is little doubt that other deposits will be found in the small ponds and swamps in this gneiss region, and those interested will do well to make search for it in any of the swales where these little swamps occur. It can be easily reached by digging, and when found can be distinguished from any other white

earth by its not effervescing with acids as white marl does, by its not becoming plastic when wet, as white clay does, and by its dissolving almost entirely in a strong boiling hot solution of washing soda.

"The importance of this material will be appreciated when it is stated that the manufacture of *dynamite*, or giant powder, at Drakeville, has reached 50,000 pounds a month. There are different grades of *dynamite*, but some of it contains 25 per cent. of infusorial earth."

An analysis of an average dried sample of the Drakeville deposit yielded the writer 47·12 per cent. of soluble silica.

Concerning the application of this curious substance in the useful arts quite a chapter might be written. During the past few years it has attracted the special attention of practical men, and so many and various have been the uses for which it has been suggested that their



FORMS OF DIATOMS FROM THE RICHMOND DEPOSITS.

bare enumeration may well excite surprise. At least one very important industry of recent origin has been practically created by it, and its employment in others is steadily growing in extent and importance. A summary of the subject in its technical aspects, with brief comments upon the more important items, is given in what follows.

The most popularly known, and perhaps the earliest application of the diatomaceous earth, is its utilization as a polishing agent for stone and metals. For this purpose, when carefully freed from grit and other impurities, its considerable hardness and its wonderfully fine state of division fit it most admirably. It may be applied wet or dry. It is well known in this connection under the name of tripoli,

so called from the locality whence it was originally brought. Under the name of "electro-silicon," "magic-brilliant," and other trade designations, the diatomaceous earth from Nevada and other localities has been extensively introduced as a polish for gold, silver, and plated ware, for which—as for tin, Britannia ware, and other metals used in the household—its wide popularity is the best proof of its excellence.

Being a very poor conductor of heat, it has been suggested and applied for surrounding ice, beer and ale cellars, fire-proof safes, steam-boilers, powder-magazines, refrigerators, etc. The results of certain experiments lately made by Refart and Co., of Braunschweig, to ascertain how this material compared with other substances generally employed for the purpose, are highly favorable to the merits of infusorial earth for this application.

Without entering into the mechanical details of the apparatus employed in these trials, it will suffice to state that in the time required to melt 100 parts (by weight) of ice surrounded by the siliceous earth, 235 parts of ice were melted in a cylinder surrounded with an equally thick layer of dry, light garden earth. Moist earth, and moist materials generally, gave still more unfavorable results. Again, for every 100 parts of ice melted when protected by the infusorial earth, 142 parts of ice protected by dry, sifted coal ashes, were melted. The results obtained with flax-shives were about the same as with the infusorial earth. These trials demonstrated that infusorial silica and flax-shives offer the greatest amount of resistance to the transmission of heat; that dry coal-ashes are far less efficient, and moist ashes still more so; and finally that earth, as compared with these, is very inferior as a non-conductor. The use of the infusorial earth is therefore highly recommended for filling in between the walls, and for covering the mason work in ice-cellars. For this purpose the following additional advantages are urged in favor of this substance, viz.:—It is extremely light,—being nearly five times as light as dry earth, and about half the weight of dry coal ashes,—and it is not combustible, remaining unaffected in the hottest fire. These properties, to quote from the published account of the above trials, "render this substance preferable to flax-shives, tan-bark, peat, sawdust, and similar materials, which are about equal to it in non-conducting quality, but which are combustible, and when kept for some time rot or moulder, shrink and settle, and might under some circumstances, take fire spontaneously" (*sic!*).

The infusorial earth, it is further claimed, will be found highly useful in fire-proof safes, as a surrounding for powder-magazines on shipboard, for covering steam-pipes and boilers, and for all similar purposes. Reference is made in some of the encyclopædias (*vide* "American Encyclopædia," iii, 268) to what are termed floating bricks, which, according to account, are made of infusorial earth, and are named in virtue of their power of floating upon water. Clay is sometimes added to the silica to assist in binding the material together. Such bricks, we are told, were made in ancient times, and were described by Posidonius and Strabo, and particularly commended by Vitruvius, Pollio, and Pliny. In 1791 they were again brought into notice by Giovanni Fabroni, in Tuscany, who, after many trials, succeeded in making bricks which would float upon water. Their strength was but little inferior to that of ordinary bricks; they are remarkable not only for extreme lightness, but also for their infusibility, and for being very poor conductors of heat; they may be held at one end while the other is red-hot. As an experiment, Fabroni constructed the powder-magazine of a wooden ship with these bricks; the vessel being set on fire, sank without explosion of the powder. In 1832 Count de Nantes, and Fournet, a mining engineer, used them in constructing powder-magazines and other parts of ships, thus lessening danger from fire. From an earlier source ("Encyclopædia Americana," ii, 266) we are informed that these floating bricks, made of agaric mineral or fossil farina,—infusorial earth,—have been found, on account of their infusibility at the highest temperatures, to be extremely useful in constructing reverberatory furnaces, pyrometers, and magazines of combustible materials, while their lightness and non-conducting qualities render them particularly useful for the construction of powder-magazines on board of ships.

In agriculture, the use of the infusorial earth has been suggested as a manure for lands poor in silica, which substance enters importantly into the constitution of the stalks and outer coverings of cereals. Quite an animated controversy, indeed, has of late sprung up as to the merits of infusorial silica as a component of fertilizers, an idea which forms the essential feature of a patent lately issued to Messrs. N. and G. Popplein, Jun., of Baltimore. It would be foreign to the purpose of this sketch to enter into a discussion of the merits of this controversy, involving as it does the introduction of certain debatable questions in agricultural chemistry; but the ideas of the Messrs.

Popplein have aroused on the one hand such warm championship, and on the other such opposition, that a concise statement of the points in dispute may not be amiss.

The manufacturers before named, proceeding from the well-known fact that the relative quantity of silica in the ash of the cereals is greatly in excess of what is required for the normal combination with the bases (potash, soda, etc.) found therein, claim that in the ordinary course of things it is impossible for Nature to furnish to cultivated lands for successive years the proper amount of silica in assimilable form for the plant, inasmuch as the liberation of this substance by the chemical decomposition of the mineral matters of the soil containing it, goes on so slowly as to render doubtful the production in many years of the amount required for a single crop. In proof of this assertion they refer to the great reduction in the yield of the wheat crop, since farmers began years ago to sell the straw of the crop that formerly was returned to the soil. For this, and other reasons less obvious, their attention was attracted to the importance of incorporating silica into commercial fertilizers—one difficulty remained to be overcome, namely, the discovery of a form of the silica—which should be assimilable by the plant. This they claim to have found in the infusorial earth,—in which the silica is in an inconceivably minute state of division,—the result of their consideration being the production of a so-called "silicated superphosphate of lime," a superphosphate with which the infusorial earth is intimately incorporated. The argument urging the importance of an abundant supply of silicic acid in available form, as an absolute necessity for the proper nutrition of cereals, is not disputed; and the manufacturers, to demonstrate the availability of the silica in the form in which they employ it, affirm that they have succeeded in proving the highly interesting and novel fact that the very minute skeletons or shells of which the infusorial earth is mainly composed are carried up *as such* into the body of the plant itself. Upon this point the following gleanings from an investigation conducted by Prof. P. B. Wilson will be read with interest:—

This chemist subjected to a microscopical examination the straw from the wheat-fields of Col. J. B. Kunkel, of Frederick County, Maryland, which had been fertilized by the silicated phosphate, his purpose being to make "a more complete investigation into the siliceous structure of the stalk, in determining whether the infusoria

passed directly as such into the sap-cells, to be carried forward by capillary force, and to finally assume their functions,—the formation of the epidermal shield for giving strength to the straw, to withstand the destructive force of high winds and beating rains, as well as a protection against the attacks of parasites."

"In making these investigations thorough precautions were observed, to cleanse the straw from all accidental impurities by washing and gentle friction, not sufficient, however, to destroy the epidermis. The organic matter was then removed by the prescribed methods, aided by my own experience.

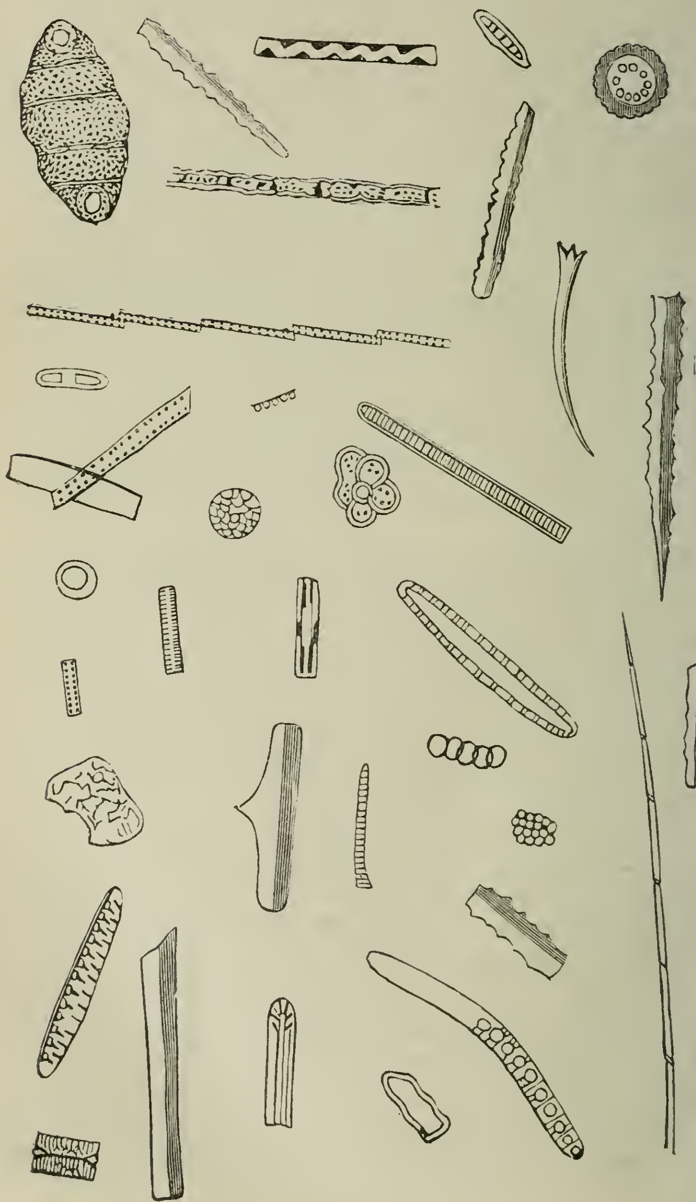
"My labors," he continues, "have been amply rewarded by one of the most enchanting views that has ever fallen to my lot to behold through twenty years of varied scientific investigations. When the epidermal siliceous coating was adjusted upon the field of the microscope, some thirty-six forms of the Diatomaceæ, which I have carefully sketched, were observed (see engraving, magnified 300 diameters) where perfect disintegration has been produced. When the structure to a great extent is retained, a marvelous interlacing of these forms presents itself sometimes side by side, at other times overlapping."

From this very interesting observation, Prof. Wilson advances a number of inferences, which, although the writer is not prepared to accept in full, are of sufficient interest to warrant their reproduction. He affirms that his investigation "overthrows all theories that have ever been advanced, that silica enters into plant structure in combination with the alkalies, the alkaline earths, or the earths proper. Chemical investigation led me to this conclusion some months since, now confirmed by that of the microscope.

"My mind was particularly impressed with the absence of the disc-like form, the *Actinocyclus ehrenbergii* and the *Actinoptychus undulatus* in their perfect state in the straw, while the other forms are common both to the infusorial earth and the wheat. My conclusions are that the varieties mentioned are too large to enter the root capillaries, for on the field of the microscope they have three to four times the magnitude of the others. This I will fully investigate during the coming summer, by making accurate measurements of rootlets and diatoms, when I will be able to obtain stalks of wheat as grown in the fields, preferring this mode of investigation to *pot culture*, to disarm controversy, and to divest the investigation of all semblance of laboratory experiment.

Forms of Diatoms found in Col. Kunkel's Straw.

MAGNIFIED 300 DIAMETERS.



"I have examined various specimens of wheat straw taken at random from the market, but have failed to find a single diatom. This to a certain extent surprised me, when taking into consideration that they are found to a limited extent in Peruvian guano. The inference to be drawn is, that the soil was not fertilized by any material into which it entered as a constituent. I mention this to guide others who may make subsequent investigations from falling into error, in case occasional Diatomaceæ are observed, as being derived from other sources than the infusorial deposits.

"These microscopic investigations show the absence of other forms of silica, that is, in granular particles in the (Kunkel) straw, they being entirely replaced by diatoms. This leads to the conclusion, that the diatom is the more acceptable for assimilation, and when sufficient infusorial remains are present, replaces any other divided form of silica. I have previously attempted to substitute silica for diatoms, as obtained from the decomposition of slags from iron furnaces, but we have failed to derive any satisfactory results. This is due to its combination as a silicate; and when liberated by stronger acids, it agglutinates into masses too hard and large to be absorbed by the plant."

Prof. Wilson concludes his report in the following glowing terms: "I look upon this application of vegetable silica to fertilizing purposes as the most important adaptation of matter for the reproduction of vegetation that has ever been discovered. It is the first step in a new direction, rationally conceived and judiciously carried out. A new impetus will be given to the study of plant physiology, which will demonstrate that more than a heterogeneous mixture of elementary bodies and their compounds are required for the production of the crops beneficial to the requirements of man."

With regard to the foregoing statements and inferences of Prof. Wilson, while not attempting to undervalue their great interest and possible entire accuracy, the writer would remark that the demonstration of the presence of the infusorial forms in the structure of the wheat stalks proves simply that these bodies are sufficiently minute to enter the root capillaries and pass into the sap-cells of the plant—nothing more. It may possibly be that, once having entered the body of the plant, they are assimilated, and made to subserve to the function of giving strength to the stalk; or, as appears to the writer equally plausible, they may simply act as so many minute

mechanical impurities drawn into the circulation of the plant, and, effecting a lodgment wherever they chance, clog up the passages, and thus actually obstruct rather than serve the process of nutrition. To follow the history of one of these forms in a living plant under the microscope, and observe its gradual dissolution, would afford the only method of positively proving the truth or falsity of either of the explanations that have been presented. While not presuming to decide so doubtful a question, it is very reasonable to believe that much of the silica of the so-called silicated superphosphate is made "available" as plant-food in solution as an alkaline salt, in which condition its assimilation by the plant presents no difficulties to the understanding. Dr. Wolf, the excellent State Chemist of Delaware, has kindly furnished the writer the following record of an analysis of the "silicated superphosphate," viz.:—

Soluble Phosphoric Acid, . .	5·855	per cent.
Precipitated Phosphoric Acid, .	3·327	"
Insoluble Phosphoric Acid, . .	trace.	
Silica, ...	20·568	"
Sulphate of Potassa, . . .	6·173	"

According to the Messrs. Popplein's published formula, the net ton of their "silicated superphosphate" contains:—

Infusorial Earth, ...	800 lbs.
Dissolved Bone, ...	800 "
Potash Salts, ...	400 "

As an absorbent and carrier of liquids of various kinds, and especially as a carrier of nitro-glycerin, the infusorial earth has been found to be most excellently adapted. It takes up from three to five times its weight of water, oil, nitro-glycerin, etc. It would doubtless prove equally valuable as a carrier of carbolic acid and other disinfectants, as a disinfecting powder, and has possibly already found application for this purpose.

In order to bring nitro-glycerin within the range of articles of transport, Nobel, who first demonstrated its value in the arts, devised the production of a powder now so extensively employed under the name of dynamite, in which the explosive oil is simply carried by the inert, pulverulent siliceous earth. The process of the preparation of dynamite may be described as follows:—

The infusorial earth must first be freed from water, organic substances, and mechanical impurities (sand, etc.). The first two are

removed by calcining at a red heat in an oven with several shelves, one above the other, on which the earth is placed and slowly pushed from the upper to the lower. The organic matter, which is considered dangerous to the stability of the dynamite, is thus burned out. It is then pressed with hard rollers and sifted, which separates it from the larger particles and grit. It is now ready for use.

Fifty pounds of infusorial earth are put into flat wooden tanks and covered with 150 pounds of nitro-glycerin, when the workmen mix them with the naked hand. Gloves of india-rubber were at first provided, but the workmen preferred to knead the mixture with the free hands. In half an hour the incorporation of the oil with the earth is complete, and the dynamite is ready for filling in the cartridge moulds. The cartridges are simple cylinders, protected by parchment paper. If ordinary paper is used the oil soaks into it, and there is great danger of premature explosion. Dynamite is a brownish gray, sometimes reddish, inodorous, pasty, greasy mass, having the specific gravity of 1·6. When ignited by an ordinary flame, it burns up quickly without detonation, and must therefore be fired with a patent exploder containing fulminate of silver inclosed in a copper capsule. It requires a heavy blow of a hammer on an anvil to explode it, and even then only the portions struck are fired. In this respect it presents great advantages over nitro-glycerin, which is easily exploded by percussion. On the other hand, the wood of the boxes in which dynamite is packed becomes by slow degrees impregnated with nitro-glycerin, and forms a most dangerously explosive material, which may give rise to serious accidents in warehouses where it is stored. As long as the nitro-glycerin is confined in the infusorial silica there appears to be very little danger, but the escape of a few drops of the oil may be the source of great mischief. The force exerted by the dynamite is much greater than that of gunpowder, and under the name of giant powder it has been largely employed in the mines of California. Other explosives, such as dualine and lithofracteur, may be said to be varieties of dynamite, having nitro-glycerin for their base, and using saw-dust or some other substance as an absorbent. All of them are powerful explosives, and must be handled with care.

For the preparation of cements and of artificial stone, a number of processes have been devised, in which infusorial earth plays a prominent part, viz.: Equal parts of infusorial silica and litharge, and

one-half part of slaked lime, stirred into a paste in linseed oil, is affirmed to become as hard as sandstone on setting, and is recommended as an excellent compound for cementing stone, metal, and wood. The following recipe, again, is pronounced to be serviceable for the production of an artificial stone for art objects. For this purpose the infusorial earth is intimately mixed with well pulverized, freshly burned lime, in the proportion of from three to six parts of the former to one of the latter. The mixture is then pressed into moulds under an addition of a very slight quantity of water. The resulting product, a silicate of lime, is formed with the evolution of considerable heat. The objects produced ultimately attain great hardness; they are perfectly water-proof, and may readily be colored with any color used in stereochromy.

In combination with sulphur, infusorial earth forms a plastic mass, called zeiodelite, but no uses have yet been made of it.

By far the most important application of infusorial earth in this direction, however, has been successfully accomplished by Mr. Fred. Ransome, of England, in the production on the large scale of an artificial stone for general purposes, to which he has given the name of apoenite. The so-called "Ransome stone," invented by this gentleman, is made by thoroughly incorporating sand and silicate of soda in a mixing mill, moulding into the form required of the block, and then saturating the same with a solution of chloride of calcium, either by exhausting the air with air-pumps, or by forcing the solution through the moulded mass by gravitation or otherwise. The result is the formation of an insoluble silicate of lime, which firmly cements the particles of which the mass is composed, and of chloride of sodium or common salt, which is subsequently removed by the free application of water. The process of washing to remove all traces of the salt from the Ransome stone, which is necessary to prevent its efflorescence and secure its proper cementation, was found to be in many cases so tedious, expensive and objectionable, that the inventor, after many experiments, devised the following process, in which the use of chloride of calcium is avoided. Mr. Ransome mixes suitable quantities of lime (or substances containing lime) and soluble silica (*i. e.*, infusorial earth) with sand, and a solution of silicate of soda or potassa, which, when intimately incorporated, are moulded as before, and allowed to harden gradually, as the silicate of lime, produced by the action of the lime on the silicate of soda, is formed.

As rapidly as the soda (or potash) of the water-glass solution is set free, it dissolves some of the infusorial silica, and again gives it up to the lime to form more cement, acting thus as the carrier of silica to the lime, until eventually all the lime is combined. In the course of the successive changes that take place, a portion of the free alkali appears to be bound at each step with the lime, as a compound silicate; and as the result of these several changes the whole of the alkali is gradually fixed, thus leaving nothing to be washed out. The mass gradually becomes thoroughly indurated, and in a very short time is converted into a very compact stone—apoenite—capable of withstanding enormous pressure, and increasing in strength and hardness with age.

In combination with magnesite (carbonate of magnesia), infusorial earth forms what is described as an excellent cement, which is manufactured in Germany, and sold under the name of "albolite."

In pottery the infusorial earth has received several important applications. When fused, for example, with borate of lime, as such is obtainable in the trade under the name of boronatrocalcite or tincalzite, an excellent glazing is produced (*Manufacturer and Builder*), which is not only useful for furnaces and pottery of all kinds, but also for enameling iron and slate, being free from lead and not apt to crack off. By fusing a mixture of infusorial earth (freed from sand) with borate of magnesia (stassfurtite), a kind of "hot-cast porcelain" is produced, having great durability and beauty. For this purpose the infusorial earth requires to be perfectly dry and free from lumps. It is introduced into the crucible in small portions and under constant stirring, until the fused stassfurtite ceases to take up more. The mass may be cast like glass, and if very liquid it may even be blown, and is thus fitted for an extensive application (*ibid.*).

Bœttger publishes the observation that when an alcoholic solution of any of the coal-tar colors is mixed with a sufficient quantity of infusorial earth, water added, and the mixture filtered, the liquid will run off clear, while the earth retains all the pigment. Hitherto the compounds of alumina have been used for the production of the so-called lakes, and it is quite probable that the above noted behavior of this material may find important applications in the arts.

The use of infusorial earth has been suggested in glass making as a substitute for sand; but it appears not to be well suited for this

purpose, the reason assigned being that it swells too much in the crucible. In the manufacture of soluble glass (water glass), for which it has likewise been tried, the impurities it contains—clay, phosphate of lime, etc.—have been found to render it somewhat unsuitable.

To conclude a sketch which has unwittingly taken considerable proportions, the following enumeration will suffice to show that the subject is by no means exhausted: A compound called diatite, devised by Merrick, consists of gum-lac and infusorial earth. The siliceous earth has been added to sealing-wax to prevent its running; it is sometimes added to paper to give it body; and to soap for the same purpose, and to add to its detergent qualities (?); and it is said to form an excellent addition to rubber, for certain uses of the latter; its addition to modeling clay is said to prevent it from cracking in moulding; and lastly, though doubtless many real or suggested applications of this curious substance have been overlooked, it is said to be of use in the manufacture of smalt and ultramarine.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS DURING THE LAST TEN YEARS.*

By Dr. A. W. Hofmann.

From the *Chemical News.*

[Continued from Vol. cii, page 360.]

It has been observed that when iron apparatus is employed for generating and conducting the hydrochloric acid gas this conveys along a certain quantity of ferric chloride, from which it cannot be freed before entering the decomposing furnace. Here the iron is deposited either as chloride, or, if the formation of chlorine has already begun, *i.e.*, as soon as watery vapor is mixed with the gases, as pulverulent oxide of iron upon the copper-sulphate. This iron dust falls from the vertical drain-pipes through the grating into the space below, whence it is easily removed. It may here, however, be remarked that Deacon, according to private communications, has latterly omitted the partition walls from the decomposition furnace, by which he effects a more

* "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

ready movement of the gaseous current without any disadvantage. In a Deacon's apparatus, which the author has seen at work in the establishment of Kunheim, at Berlin, the partition walls and the vertical drain-pipes had both been omitted without any detriment being observed in the course of several months' working.

After the mixture has passed through the decomposing furnace it consists of chlorine, water, nitrogen, superfluous oxygen, and unconsumed hydrochloric acid. The latter is condensed in an ordinary condensation apparatus, charged with dilute hydrochloric acid, or water, the temperature of the gases having been previously reduced by air-coolers. The gas is next freed from the accompanying water by passage through a tower filled with chloride of calcium, or, better, through a coke-tower, down which sulphuric acid flows. The gaseous mixture is then fit for absorption in the chloride of lime chambers. As a matter of course a drying apparatus is superfluous if a watery liquid is to be saturated with chlorine, as in the preparation of potassic chlorate.

For the latter purpose Kunheim utilizes the chlorine obtained on Deacon's method. The chlorine is here so completely absorbed by the milk of lime through which it passes that mere traces are contained in the air escaping from the exhauster. The draft in the entire apparatus is kept up by any aspiratory arrangement beyond the chloride of lime chambers and measured by an anemometer constructed by Hurter. The latter consists of a U-tube of 5-16ths c. m. internal diameter, with legs about 25 c. m. in length. As one leg of this tube is always in communication with the gaseous current, the pressure occasioned by the current is always shown in the other leg by the tube by the displacement of a liquid therein contained (ether). The U-tube is fixed so that the leg containing the liquid lies flat on a graduated inclined plane, which may be raised or lowered on a frame fitted with a level. The meniscus of the liquid is thus extended diagonally, and the small vertical divisions of the scale are magnified into long horizontal degrees. Kunheim uses a simple upright U-tube filled with ether.

The greatest practical difficulty in the Deacon's chlorine process lies in the enormous volume of gas which has to be dealt with, and consequently in the large dimensions required for the chloride of lime chambers. But Deacon has endeavored to combat these difficulties. He compels the gases to take such a course that they are systemati-

cally deprived of chlorine. They meet at first with chloride of lime almost saturated, then, as they lose their chlorine they pass over lime less and less chlorinized till they finally pass out into the atmosphere completely exhausted over fresh hydrate of lime. The arrangements by which this systematic saturation of the lime is produced are of a twofold nature. In the first place chambers are employed in which the lime lies on gratings and which are so connected with each other that the chlorine streams through them successively. As soon as the lime in the chamber nearest the generating apparatus is saturated it is thrown out of connection with the current of chlorine, is charged with fresh lime, and takes its place at the end of the series, whilst a chamber containing lime nearly saturated receives the concentrated portion of the gaseous current. The second kind of methodic saturation is the following, in which is applied the principle of Hasenclever and Helbig's pyrites furnace:—

In a tower are several stories of sloping plates of slate, forming a smaller angle with the perpendicular than the outer surface of the heaped up chloride of lime is capable of taking. In every story the direction of the plates, which are parallel to each other, cuts the plane of the plates, likewise parallel to each other, in the next higher and next lower story. Thus intervals are produced which extend in zigzag from below upwards. At the lower end of each of these intervals is a shovel-wheel by whose revolution the speed of a powder sliding over the plates can be regulated. Into this tower the lime is thrown by means of a hopper and slips from plate to plate till its further fall is stopped by the rollers. But as the falling lime cannot form so acute an angle with the perpendicular as the plates it does not completely fill the interstices, but leaves in every link of the zigzag a wedge-shaped space, through which the gases are compelled to ascend from stage to stage. Hence, as the lime moves constantly downwards in an opposite direction to the current fresh lime enters above, and saturated chloride is taken out below. To obviate incidental stoppages in the motion of the lime there are here and there in the tower openings fitted with valves. This apparatus can scarcely be adopted in practice, as chloride of lime, from its tendency to clog together, moves but slowly down an inclined plane, whence frequent stoppages would be inevitable.

The last mentioned apparatus, suitably modified, is recommended by Deacon for the preparation of salt-cake from diluted chlorine,

sulphurous acid, steam, and salt. Instead of lime he causes salt to glide down a tower strongly heated, whilst a mixture of diluted chlorine, sulphurous acid, and steam ascends.

The hydrochloric acid thus formed is condensed and re-converted into chlorine, whilst the sulphuric acid formed by the oxidation of the sulphurous acid converts the salt into sulphate.

When Deacon's process was first made known, its industrial practicability was strongly doubted. The principal difficulties were considered to depend on the regulation of the temperature, the enormous volume of gases to be dealt with, and the considerable consumption of fuel. Since, however, the two former obstacles have been overcome by the inventor in the manner described, the process seems more and more available. In Great Britain at least thirteen establishments are already working on the new process, and in Germany two (Kunheim and the Rhenania, the latter experimentally). According to Deacon's statement more than 1,000 kilos. of chloride of lime at 35 per cent. are obtained from 1,500 kilos. of salt, with a consumption of 1,000 kilos. small coal. A small portion of the hydrochloric acid gas is lost from causes not as yet fully ascertained, but the portion which passes undecomposed through the apparatus is entirely recovered.

Besides Deacon's process several other proposals have been made for obtaining chlorine, and in some cases without the use of manganese, but they have not been adopted in practice.

Thus Macfarlane*[1] hoped to obtain soda and chlorine simultaneously by passing air over an ignited mixture of copperas and salt. Sulphate of soda and ferrous chloride are formed, which latter is converted into iron oxide and chlorine by the oxygen. The mixture of sulphate of soda and oxide of iron on reduction with coal and lixiviation with water yields sodium hydrate (easily convertible into soda) and iron sulphide, which is reconverted into copperas on exposure to the air. Clemm*[2] endeavored to use chloride of magnesium for the preparation of chlorine; he mixed the magnesium chloride with manganese and decomposed it by a current of superheated steam.

Chloride of lime, the only form in which free chlorine is found in the market, has latterly been the subject of a number of published

*[1] Macfarlane, *Dingl. Pol. Journ.*, clxxiii, p. 129.

*[2] Clemm, *Dingl. Pol. Journ.*, clxxiii, p. 127.

papers, which have not led to any material change in the manner of its preparation. The causes of its spontaneous decomposition, sometimes attended with explosions, and formerly not infrequent, have been investigated. To avoid such misfortunes it is recommended not to saturate the lime when too hot, and not to carry the process to the uttermost attainable point, and also not to pack it in barrels when still too recent and too moist. The gas which occasions the explosion of the chloride of lime casks has been found to be oxygen, and on such spontaneous decompositions the mass of the compound is converted into a mixture of chloride and chlorate of calcium. Interesting dissertations of a more scientific character concerning the nature of chloride of lime have been published by Kolb, Riche, Bobierre, Scheurer-Kestner, Tschigianjang, Fricke and Reimer, Crace-Calvert, and Göpner, which unfortunately cannot be reported on in brief, as the results of these researches are in part, at least, contradictory. The final solution of the question as to the constitution of chloride of lime is by no means solved.

Potassium Chlorate.—No important change in the manufacture of the chlorate of potash has been introduced in the last few years. Now, as well as formerly, it is everywhere made according to Liebig's original process, hot milk of lime being saturated with chlorine, and the calcium chlorate, formed simultaneously with calcium chloride, being decomposed by potassium chloride.

In England, which produces the bulk of the chlorate of potash of commerce, it is at present, according to Lunge, obtained in the following manner:*

For saturating the milk of lime are employed two iron cylinders, lined with lead, connected with each other, and fitted with agitators. These cylinders communicate with each other, and with the chlorine still by means of tubes, and in such a manner that the contents of the one approach the state of complete saturation, whilst in the other any chlorine which may have escaped absorption is taken up by fresh milk of lime. As soon as perfect saturation has been attained in the first receiver, its contents are replaced by fresh milk of lime, and the current of chlorine is turned so that it may first enter the second apparatus. The solution of chloride and chlorate of calcium thus obtained has a rose-red color, due, according to some authorities, to permanganic acid; but which, according to others (Crace-Calvert),

* Lunge, *Dingl. Pol. Jour.*, cxxcix, 489.

appears also in the absence of manganese. In fact, this rose color of the liquid is observed also as a sign of the complete saturation of the liquid where the chlorine employed is obtained without the use of manganese as at Kunheim's works at Berlin, where chlorine obtained by Deacon's process is used in the preparation of chlorate. The red liquid after clearing with chloride of potassium is evaporated down to the sp. gr. 1·28 and allowed to crystallize. The liquid drawn off from the first crop of crystals is further evaporated down to 1·35, when a second smaller quantity of chlorate of potash is obtained. A portion, about 12 per cent. of the chlorate of potash remains in the mother liquor, which can therefore be treated as a source of chlorine. The crystals obtained are still contaminated with chloride of potassium and iron. To remove these impurities the crude salt is dissolved in the smallest possible quantity of hot water, 2·5 kilos. of soda are added to 10 hectolitres of the solution, and after the carbonate of lime and oxide of iron have been deposited it is allowed to crystallize. The crystals are dried in drying-rooms; the larger ones are sold without further treatment, and the smaller ones are ground between rollers. This process, in spite of every care, is sometimes attended with explosions. Lunge therefore recommends to crystallize the salt with constant agitation, and thus obtain it as a crystalline powder. In this manner the purification might also be more readily effected, as easily-soluble salts could be removed from the crystalline powder by merely washing with water.

Whilst considerable quantities of chlorate of potash are manufactured in England, this branch seems to be scarcely remunerative in Germany, where the same method of preparation is adopted. Several establishments have recently abandoned the manufacture. According to the experiments of F. Hobrecker, 100 parts of chlorate of potash require—4431·0 hydrochloric acid (20° B.); 772·0 manganese (65 per cent.); 418·0 lime; 72·7 chloride of potassium (92 per cent.); 2262·0 lignite.

Bromine.—However considerably the production of bromine had increased in the earlier decennial periods of its manufacture on the large scale, and however easily vast quantities of this body could be made available for the arts, its industrial applications, and consequently its production, have increased very little in the last few years. Whilst formerly the raw material for its preparation was derived from the mother-liquors of salt springs and from sea-water, especially

that of the Dead Sea, which, though richly bromiferous is too remote from the centres of consumption for chemical products, a new source has been discovered in the mother-liquors of the clearing salts (Abraum salz) of Stassfurt, which can be easily adapted to the demand. In spite of the quantity of bromine which can be obtained at Stassfurt it is merely a by-product of the potash trade, as, in consequence of the small demand and low commercial value, the cost of production falls little short of the market price. The utilization of the Stassfurt "abraum" salts as a source of bromine dates from the year 1865, when A. Frank introduced this branch of industry in order the better to compete with the potash from kelp and from salt-springs, and also in the hope of superseding the use of iodine in the manufacture of colors.

When, in consequence of the extensive opening of manufactories for the utilization of the "abraum" salts, an over-production of the salts of potash occurred, other establishments felt induced to enter upon the preparation of bromine, but without accomplishing anything worthy of note in this direction.

Rich sources of bromine were also discovered in North America, and have been worked with great success.

The product, however, does not arrive in Europe as liquid bromine, since ships do not generally receive it among their cargo. It is exported chiefly as bromide of potassium. But considerable as is the quantity of bromine produced in North America there is no foundation for the fear that it may occasion any appreciable depression of the Stassfurt trade, since bromine is obtained in America as a main product, whilst in Stassfurt it plays merely the part of a by-product of the potash manufacture.

The demand for bromine and its compounds depends on its applications in medicine, photography, and scientific chemistry. The hope of seeing its hydrocarbon compounds extensively employed in the manufacture of coal-tar colors in place of the corresponding iodides has not been fulfilled, in spite of the present greatly increased price of iodine. One obstacle which stood in the way of the application of brom-ethyl and brom-methyl for the purpose in question, *i.e.*, the great volatility of these compounds, has been overcome by Dr. A. W. Hofmann,* who proposes to cause bromamyl—which boils at the far higher temperature of 120°—to act upon the colored bases, to be

* A. W. Hofmann, *Ber. Chem. Ges*, 1869, 441.

ethylated or methylated simultaneously with methylic or ethylic alcohol, thus forming brom-ethyl or brom-methyl along with amylic alcohol. Still the small reactive power of the bromides as compared with the iodides, the inferior brilliance of the colors produced with the aid of the former, the difficulty of recovering the bromine as completely as iodine in consequence of its volatility, have prevented bromine from effectively competing with iodine in this department. Still the hope that bromine may on further investigation attain importance in tinctorial chemistry has not been abandoned. Certain manufactories, both English and German, use a mixture of bromethyl, which boils at about the same temperature as iod-methyl and brom-methyl. The reporter is informed on good authority that the color works of Huddersfield and of Barmen still draw large supplies of bromine from Stassfurt.

The use of bromine as a disinfectant in the form of an aqueous solution, introduced during the North American and Franco-Prussian wars, has remained very limited, although it possesses several advantages as compared with chloride of lime. In hospitals the use of bromine occasions much less irritation in the respiratory organs than that of chlorine.

Although, as has been stated, bromine finds scarcely any application in great manufacturing operations, its production is still important, as appears from the report of Chandler.*[1] According to this authority 62,500 kilos. were annually obtained in North America alone in 1869 and 1870, principally in Tarentum, Sligo, Natrona, Pomeroy, Ohio, and Kanawha. Stassfurt produced in the year 1873, 20,000 kilos.; and England and France together about the same quantity.

From the foregoing it will be readily inferred that there is little novelty in the methods of extracting bromine.

Leisler*[2] took out an English patent for a method of obtaining bromine and iodine. He decomposes the bromiferous lyes with a mixture of hydrochloric acid and bichromate of potash in an iron still furnished with a capital of lead or stoneware. The vapors of bromine along with water are led into a receiver containing iron turnings. Bromide of iron is formed, which dissolves in the water, and is either converted into other metallic bromides by the customary

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*[1] H. Chandler, *Chemical News*, 1871, No. 586, p. 77.

*[2] L. Leisler, *Dingl. Pol. Journ.*, clxxix, 386. *Wagner Jahresbericht*, 1866, 179.

methods, or is treated for free bromine with sulphuric acid and bichromate of potash. This process has never been reduced into practice, and for Germany at least appears too expensive.

In Stassfurt, therefore,*[1] the method has been followed which had been used for the extraction of bromine in the salt works of Schönebeck, Artern, and Neusalz, consisting of the following operations: The mother-liquor of carnallite at 35° B. freed as far as possible from chloride of calcium by refrigeration, is concentrated to 40° B. by further evaporation. According to Frank the concentration cannot be carried so far, as, in consequence of the partial overheating of the lye at the bottom of the pan, bromine is inevitably wasted in the form of hydrobromic acid. On cooling to 25° a quantity of chloride of magnesium, $MgCl_2+6H_2O$, and the remaining mother-liquor contains from 0·3 to 0·5 bromine as bromide of magnesium. It is placed in a sandstone apparatus resembling those used for the preparation of chlorine with the corresponding quantity of manganese and hydrochloric acid, and heated by the introduction of a current of steam. The red vapors which are evolved about a quarter of an hour after the steam is turned on are condensed in a lead worm, cooled in water, and are collected as liquid bromine in Woolff's bottles. The crude bromine is re-distilled in glass retorts for further purification. A sand-stone apparatus can be charged six times in twenty-four hours. In order to obtain the bromine free from chlorine it is agitated with a solution of bromide of potassium, from which bromine is liberated equivalent to the chlorine present, whilst chlorine of potassium is formed (Falières).

As leaden worms are very rapidly destroyed by liquid bromine, though very slightly attacked by bromine vapors, Frank*[2] employs condensing tubes of earthenware. To separate the bromine from the chloride of bromine simultaneously evolved he avoids a too perfect refrigeration, and conducts the more volatile products, including the chlorine, into a receiver charged with iron turnings or with potash lye. The crude bromine in the first receiver is then completely freed from chlorine and from sparingly volatile organic bromides which are usually present by fractionated distillation.

Several methods for obtaining the bromides of the alkalies and alkaline earths deserve notice. Henner and Von Hohenhausen*[3]

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*1 F. Michel, *Wagner Jahresbericht*, 1867, 194.

*2 Private communication.

*3 Henner and Hohenhausen, *Dingl. Pol. Journ.*, clxxiii, 1864, 221.

prepare the bromides of calcium, barium, and strontium by diffusing the respective hydrates in water, decomposing with bromine, evaporating till the formation of crystals begins, and mixing the liquid with alcohol, which precipitates the last portion of the bromate formed. The bromide is then obtained from the liquid, and a further portion is procured by heating the bromate with charcoal. C. Wendler*[1] proposes to prepare the bromides of the alkaline earths according to Rud. Wagner's approved method for the manufacture of the corresponding iodides, *i. e.*, by the action of bromine upon the sulphites.

According to A. Faust*[2] Bœdeker obtains the bromides as follows: Bromide of sulphur is prepared from 20 parts flowers of sulphur and 240 parts of bromine, and gradually poured into the milk of lime made from 140 parts of quicklime, or into a corresponding solution of baryta. The bromide of sulphur in contact with the hydrate of the alkaline earth is decomposed into a metallic bromide and a sulphate. The latter is removed by the addition of alcohol and subsequently of lime. The solution of calcic or baric bromide can either be used for obtaining those salts, or for preparing the sodic, potassic, or ammonic bromide by decomposition with the corresponding carbonate or sulphate.

Casthelaz*[3] prepares the bromide of sodium by forming, in the first place, bromide of ammonium by dropping bromine into liquid ammonia, and decomposes this by the addition of an equivalent quantity of caustic or carbonated soda.

Falières points out*[4] that iodine present in bromide of potassium may be removed by agitation with free bromine.

Of all these methods of preparing bromides, especially bromide of potassium, which is most in use, none is practiced on the large scale. Either the ferroso-ferric bromide is decomposed by the addition of carbonate of potassa, or vapors of bromine are conducted into potash lye, and the potassic bromate formed along with potassic bromide is decomposed by ignition with charcoal powder. The preparation of bromide of potassium and the bromides of iron is conveniently combined with the manufacture of bromine. Since 1867 Frank condenses bromine

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*[1] C. Wendler, *Wagner Jahresber.*, 1863, 291.

*[2] A. Faust, *Archiv d. Pharm.*, clxxxi, 216. *Wagner Jahresber.*, 1867, 196.

*[3] Casthelaz, *Monit. Scient.*, 1870, 65. *Chemical News*, 1870, No. 532, 58; and 547, 238. *Wagner Jahresber.*, 1870, 195.

*[4] Falières, *Wagner Jahresber.*, 1872, 274.

in a set of three Woolff's bottles, the first of which slightly cooled, receives liquid bromine, whilst the second contains bromide of potassium or ferrous bromide, and the third potash lye or iron turnings. The chloriferous bromine vapors escaping from the first slightly cooled receiver pass through the solution of bromide and are freed from their chlorine, in the place of which bromine escapes from the bromides and arrives in a pure state into the iron turnings or the potash lye contained in the third bottle, in which pure bromides are at once obtained.

We have already mentioned that a large proportion of bromide of potassium is obtained from the ferroso-ferric bromide. The manufacturers of bromide of potassium are not under the necessity of preparing the iron compound themselves from condensed bromine. It is obtained at the Stassfurt bromine works, and is sold in the form of a paste containing from 65 to 70 per cent. of bromine. As it can be packed in vessels of stoneware and tinned iron and even in wooden casks, it is the most convenient form for the carriage of bromine, which in the free liquid state, is difficult to pack and dangerous to convey.

We may here also mention the bromiferous artificial saline mixtures prepared in imitation of the salts obtained from mineral springs.* At Vienna the mother-liquors and their salts of Kreutznach, Kœsen, Wittekind, &c., were exhibited by Frank, and by the United Manufactures of Leopoldshall. Finally, we must mention the arrangements adopted for preserving the workmen from the injurious action of bromine. It appears in fact, that when these are applied no danger to health is to be apprehended. In the selection of workmen it is primarily essential to see that they have well-developed respiratory organs, and are free from any predisposition to asthma and catarrhal affections. The use of spirituous liquids must be strictly interdicted, as the irritability of the mucous membranes which they produce is exceedingly dangerous. On the other hand, a generous diet is recommended, and especially the abundant use of fatty and mucilaginous articles, butter, bacon, &c.

(To be continued.)

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* In Germany such saline mixtures are used under the name of "bath salts" (*bade-salze*).